THE EFFECTS OF A MATHEMATICAL WORD PROBLEM SOLVING STRATEGY ON PROBLEM SOLVING PERFORMANCE BY MIDDLE SCHOOL STUDENTS WITH MILD DISABILITIES

BY

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By

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Students with mild disabilities have been found to have deficits in many academic areas, including the application of mathematical operations. Many of these students lack strategies and techniques for assisting them in solving mathematical word problems. A variety of approaches and techniques have been presented as effective practices for teaching students to solve word problems.

A word problem solving strategy which included direct and mnemonic instruction was developed for teaching secondary school students with mild disabilities to solve mathematical word problems. An investigation was conducted to determine if students with mild disabilities were able to acquire and retain a word problem solving strategy, and to determine whether subjects were able to apply the strategy to solving multistep mathematical word problems. A multiple probe design across students (N=10) was used to the evaluate the effects of the strategy. Four of the students were identified as having emotional handicaps; six were identified as having specific learning disabilities.

The independent variable of this investigation was a word problem solving strategy that incorporated effective, empirically-tested instructional techniques developed by the Institute for Research in Learning Disabilities at Kansas University.

The dependent variables were the numbers of appropriate and inappropriate marks made by the subjects when applying the strategy, and the numbers of problems correctly and incorrectly solved by the subjects. The problems were single step word problems and multistep word problems. Data from multistep word problems were collected during the generalization phase of the investigation.

An analysis of the data suggested that students with mild disabilities were able to acquire, retain, and generalize the word problem solving strategy. Social validity measures revealed that teachers and students expressed satisfaction with the strategy training in terms of importance and effectiveness. Implications for providing word problem instruction to students with mild disabilities are discusssed.

CHAPTER I

INTRODUCTION TO THE PROBLEM

Introduction

Researchers of special education programs have indicated that graduates with disabilities and dropouts are not prepared to make successful transitions from the school environment to the world of work (Edgar, 1987; Fardig, Algozzine, Schwartz, Hensel & Westling, 1985). Because many of these students appear to be ill-equipped to handle the obligations and responsibilities for successful independent living, these researchers have stressed the need for appropriate changes in curriculum and outcomes. Arguments for the implementation of either a functional basic skills curriculum (Fredericks & Evans, 1987), a basic skills remediation approach, or a strategic learning skills approach (Deshler & Schumaker, 1986) have been discussed. However, all agree on the need for exceptional individuals to become functional and independent participants in the community.

To become functional and independent, all students, including students with disabilities, need to become competent in mathematics (National Council of Supervisors of Mathematics (NSCM), 1989). The NCSM (1989) reported that competencies in problem solving and the application of mathematics to everyday situations are two of twelve components that are necessary for preparing students to become responsible adults.

It is important that exceptional individuals possess skills that would enhance their future education and employment options. Garofalo and Mtetwa (1990) found that mathematics educators believe that mathematics is useful for all individuals--as workers, as consumers, and as educated citizens; and that the study of mathematics facilitates the development of reasoning and problem solving skills.

The NCSM and Garofalo and Mtetwa are not alone in identifying the importance of problem solving and the application of mathematics to everyday situations. Cawley (1985), Sharma (1985), and Webster (1985) share this perspective. Cawley (1985) and Sharma (1985) state that students with mild disabilities need to be taught and provided practice in applying computational and problem solving skills to real word problems.

Webster (1985) indicated that the primary focus of a mathematics program for mildly disabled students should be on developing problem solving skills. He further stated that teaching should stress the comprehension of the meaning of mathematical word problems and the computational operations required for solving the word problems. Webster noted that the goal of comprehension activities is to teach mildly disabled students to reason logically when confronted with problem solving situations.

Acceptance of the positions of the NCSM, Garofalo and Mtetwa, Cawley, Sharma, and Webster indicates that modes of instruction need to be developed to allow students to demonstrate and apply problem-solving and higher order thinking skills to everyday life. Acceptance of this position also requires that new procedures for teaching students to solve problems must be based upon effective, research-based methods and techniques.

The need for viable instructional techniques has led researchers in special education and mathematics education to explore a variety of interventions. First, researchers have found that direct instruction procedures are effective methods to help students with disabilities to make progress in basic academic skill areas (Englemann & Carnine, 1982; Gersten, Carnine, & Woodward, 1987; Gersten, Woodward, & Darch, 1986; Roehler & Duffy, 1984) . Second, metacognitive and cognitive behavior modification techniques have received support as being effective procedures for teaching disabled learners to acquire basic skills (Wong, 1985). Third, Mastropieri and Scruggs (1989) report that mnemonic instruction, although confined to social studies, reading, and science instruction, is another effective method to facilitate the acquisition and demonstration of skills by students with mild disabilities. Finally, training students in problem solving should also include procedures designed to promote and enhance the generalization of the desired skills and competencies (Blankenship,1985; Deshler, Schumaker, Alley, Warner, and

Clark,1982; Ellis, Lenz, and Sabornie, 1987a, 1987b; Stokes and Baer, 1977).

Statement of the Problem

This study was designed to investigate the effectiveness of a learning strategy developed to assist students with mild disabilities solve simple mathematical word problems. The treatment strategy consisted of portions of problem solving processes that have been found to be effective in assisting students to solve word problems. These techniques included the identification of the key information items, graphically displaying the problem, and writing out the problem mathematically. A mnemonic device to assist the student in performing the solving of word problems was also included. In addition to effectiveness, retention of strategy use was examined. Generalization measures were also obtained for the solving of multi-step word problems. Performance measures were collected to address the following questions:

1. Do mildly disabled students acquire a mathematical problem solving strategy which includes direct and mnemonic instruction?
2. Do mildly disabled students retain a mathematical problem solving strategy which includes direct and mnemonic instruction?
3. Do mildly disabled students generalize a mathematical problem solving strategy which includes direct and mnemonic instruction to the solving of multi-step mathematical word problems?

Rationale

In instructional settings, many techniques have been implemented to remediate mathematical learning difficulties experienced by mildly disabled students. A majority of the research in mathematic skill remediation for learners with mild disabilities has been in the area of computation (Blankenship & Lilly, 1981; Blankenship, 1983; Haring, Lovitt, Eaton & Hansen, 1978). However, relatively few techniques and applications dealing with the remediation of word problem solving with mildly disabled students have been studied (Blankenship,1985).

Five experimental studies conducted to investigate techniques and applications for remediating word problem solving deficits in mildly disabled students are reported. In three of the five studies, researchers implemented direct instruction procedures (Darch, Carnine, & Gersten, 1984; Jones, Krouse, Feorene, & Saferstein, 1985; Wilson & Sindelar, in press) and found that students taught problem solving under direct instruction formats were able to solve word problems significantly better than in non-direct instruction formats. The other two studies (Montague & Bos, 1986; Smith & Alley, 1981) used instructional procedures with a cognitive processing orientation.

All of these studies report success in teaching mildly disabled students to solve mathematical word problems. None of the techniques used in these studies incorporated mnemonics as an instructional aid for solving mathematical word problems. Of five studies involving the use of mnemonic devices to facilitate the acquisition and retention of new information and skills, there is only one study (Machida & Carlson, 1984) that deals with the use of mnemonics in mathematics instruction.

Although it is important for individuals to acquire and become competent in the use of mathematical computation, the ability to apply mathematical concepts and procedures must also be exhibited. Stokes and Baer (1977) indicate that the generalization of skills taught to individuals must be programmed, and that the individuals involved need to be trained in how to internalize and functionally utilize those skills. Stokes and Baer (1977) further stated that for "a therapeutic behavioral change to be effective, often (not always) must occur over time, persons, settings, and the effects of the change sometimes spread to a variety of related behavior " (p. 350).

Researchers cannot expect individuals to demonstrate and possess necessary skill competencies in various settings and under various conditions without having incorporated generalization techniques into the treatment program. Wong (1988) supports this position and notes that one of the major problems confronting researchers is the lack of programmed generalization phases in many strategy treatment approaches. Therefore, it is important that students be provided assistance in generalizing the word problem solving strategy to other setting and situations. The word problem solving strategy designed for this study provides students with instructional procedures to enhance students abilities to acquire, retain, and generalize the strategy to the solving of mathematical word problems.

Definition of Terms

The following section presents terms and their definitions that are used in this study. The terms are critical in understanding implementation procedures and results of the study.

Celeration is "a measure of frequency change with respect to time" (Johnson & Pennypacker, 1980, p. 127). The frequency change refers to a specific behavior being recorded.

Cognitive behavior modification involves the use of thought processes for the purpose of influencing and modifying an individual's behavior. Cognitive behavior modification incorporates a detailed and explicit drill in the sequence of behaviors necessary to accomplish a task (Meichenbaum, 1977; Stone, 1989).

Cognitive strategy is an internally organized skill that selects and guides the internal processes involved in the solving of novel problems. This process is also a skill that allows learners to manage their own thinking (Gagné & Briggs, 1974).

Condition length is the length of time a specific condition is in effect (Tawney & Gast, 1984).

Direct instruction is a comprehensive model that covers the details of curricular design, teaching techniques for low performing students, implementation policy, and teacher training. It is characterized by these six critical features. These features are

1. An explicit step-by-step strategy of the skill being taught;
2. Development of mastery at each step in the instructional process;
3. Strategy procedures or process correction procedures for dealing with student errors;
4. Gradual fading from teacher directed activities toward independent work;
5. Use of adequate, systematic practice with a range of examples; and
6. A cumulative review of newly learned concepts. (Gersten, Carnine, & Woodward, 1987).

Generalization is the occurrence of relevant behaviors under different, non-training conditions (i.e., across subjects, settings, people, behaviors, and time) without the scheduling of the same events in those conditions as had been scheduled in the pre-arranged training conditions (Stokes & Baer, 1977).

Learning strategies are techniques, principles or rules that serve as facilitators for the acquisition, manipulation, integration, storage and retrieval of information across settings and situations by individuals (Alley & Deshler, 1979) and are "designed to teach mildly disabled students how to learn and cope with the demands of secondary and post-secondary settings" (Lenz & Deshler, 1990, p. 85).

Level is "the magnitude of the data as indicated by the ordinate scale value" (Tawney & Gast, 1984, p. 161).

Level stability is "the amount of variability or range in data point values, in a data series" (Tawney & Gast, 1984, p. 161).

Maintenance is an instructional procedure designed to determine whether a specific behavior is still being exhibited at criterion. For the purposes of this study, maintenance will be measured 1 week after instruction.

Metacognition is the self-awareness of one's cognitive processes, cognitive abilities, and the relationship between one's cognitive resources and task presented. Metacognition also refers to the self-regulation of one's behavior (Flavell, 1977).

Mildly disabled individuals are those persons that have been identified and classified as being learning disabled, emotionally disabled, or educable mentally disabled and are provided educational services in resource rooms or varying exceptionalities classrooms.

Mnemonics are words that are used to describe objects, events, situations that facilitate and enhance an individual's memory (Nagel, Schumaker, & Deshler, 1986).

Probe is a experimenter-made instrument assessing the skills and abilities. With regard to this study, probes focus on the solving of mathematical word problems, and serves as an "ancillary measurement system for applied behavior analysis and precision-teaching systems" (Cawley, 1984, p. 70).

Problem solving is a process by which an individual uses previously acquired knowledge, skills, and understanding to satisfy the demands of unfamiliar situations and events (Krulik & Rudnick, 1982).

Retention is the ability of an individual to recall information previously learned. For this study, retention will be measured 3 weeks after instruction.

Trend refers to the direction and slope of a series of plotted data points across time (Tawney & Gast, 1984).

Verbal mediation consists of talking to one's self in relevant ways when confronted with something that needs to be learned, a concept to be understood, or a problem that has to be solved (Jensen, 1966).

Delimitations

This study was delimited by the political boundaries of Alachua County and the respective school district included within those boundaries. Classroom teachers selected to participate in the study expressed an interest to be involved in the experimental procedure. The teachers were employed in one middle school, one junior-senior high school, and one special school located in Alachua County. The three teachers were all assigned mathematics teaching responsibilities. The teacher at the special school did not teach elementary school-aged children.

Students consisted of males and females who were experiencing difficulty with the solving of mathematical word problems. Students with age levels corresponding to sixth, seventh, and eight grade levels were asked to participate in the study. Subjects came from all social economic status levels, and from all racial and ethnic backgrounds found in the Alachua County school system.

Limitations

Because this study included only students with mild disabilities found in three specific schools, the findings should not be generalized to other disabled students with sensory disabilities or with moderate to severe intellectual disabilities. The findings should also not be generalized to elementary disabled and non-disabled students as they were not included in the study. Extrapolation of these results to mildly disabled middle and high school students in regular and special schools outside of the Alachua County area should be exercised with caution.

Summary

The application of metacognitive and cognitive behavior modification principles for the acquisition of mathematical problem solving skills by individuals has created much interest. Research in which the effectiveness and efficiency of techniques using these principles is greatly needed to promote effective programming.

Lack of attention by researchers in the areas of programming for the generalization of skills has also hindered the development of effective instructional techniques designed to increase functional skills competency among individuals with learning difficulties. The instructional formats found in direct instruction procedures appear to be feasible avenues for further exploration by individuals concerned with the acquisition of functional problem-solving skills by exceptional individuals.

A review of the literature relevant to the study is presented in Chapter II. The review contains literature pertinent to mathematical problem solving, metacognitive and cognitive behavior modification, direct instruction, and generalization. Methodological procedures for the implementation of the treatment procedures and data analysis is presented in Chapter III. The results of the study and their implications are reported and discussed in Chapters IV and V. The appendices contain permission letters, treatment scripts, pretests and posttests, as well as other documents.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of Chapter II is to review relevant research and literature related to the development and teaching of exceptional students a strategy for solving mathematical word problems. The chapter contains three major sections. The first section explains and clarifies the selection criteria for the types of research and pertinent literature that will be reviewed. The second section contains a review of research and pertinent literature and provides a foundation for the experimental treatment. The final section includes a summary and implications of previous research as it relates to the study. Overall, the review of the literature is organized to address the following questions:

1. How are the concerns of mathematics educators related to the concerns of educators of the mildly handicapped?
2. What research-based techniques exist in the mathematics literature for teaching word problem solving?
3. What techniques and procedures exist in the special education literature for teaching exceptional students to acquire and retain information?

4. What are effective instructional techniques and procedures that are used for teaching learners to generalize newly acquired skills?

Selection of Relevant Literature

Data based articles and cumulative data based reviews were examined, summarized, and presented as an initial step in locating relevant research that addressed the issues posed by the four organizational questions. The initial step in locating relevant research consisted of defining the parameters of the literature search.

The following criteria were used to select research reports and articles to be reviewed:

1. Subjects participating in the study were of school age (Kindergarten through 12th grades).

2. Subjects were receiving educational services in either a public, private, or special educational setting.

3. Experimental questions examining the effects of instructional techniques on the solving of mathematical word problems, the effects of effective instructional techniques for the acquisition and retention of information by exceptional students, or the effects of instructional techniques designed to facilitate and promote generalization of skills were identified and reviewed. Experimental or investigatory studies in which the components or variables that facilitate the successful resolution of mathematical word problems were also included.

4. Data obtained by researchers supporting the efficacy of instructional procedures were obtained from either single subject experimental research designs or from traditional group experimental research designs.

In order to find the information, extensive computer assisted searches, as well as the visual inspection of Educational Resources Information Center (ERIC), and Resources In Education (RIE) reference books were used. The following computer search networks: Research Libraries Information Network (RLIN), Library Users Information Service (LUIS), and the Online Catalog of the Library of Congress (OCLC) were used.

In addition to the previous sources, the electronic card cataloging system of the State University Systems (LUIS), Current Index of Journals in Education, Exceptional Child Education Abstracts, Resources in Education, and reference sections of related articles and books were used. The computer assisted search resulted in thirty-one research reports that met the above criteria.

A review of various types of research and procedures was conducted. This review focuses on literature related to the need for mildly handicapped individuals to learn effective mathematical problem solving skills. It includes an examination of mathematical word problem research, mathematical problem solving instructional procedures, and effective instructional procedures to promote skill acquisition and the generalization of new skills.

Review of Studies Associated with Mathematics Instruction and Learning Disabled Individuals

Educators have voiced concern over the acquisition of functional skills. The National Council of Supervisors of Mathematics (NCSM) addressed the need for all school-aged youth to acquire competence in functional mathematics skills (1989). Officials stating the policies provided by the NCSM membership indicated that students must understand mathematical concepts and principles; be cognizant of when and how to use computational skills; and must develop proficiencies in problem-solving and higher order thinking skills (NCSM, 1989).

According to NCSM officials, the 12 components of essential mathematical skills which students must have high degrees of competency are problem-solving, communicating of mathematical ideas, mathematical reasoning, application of mathematics to everyday situations, being alert to the reasonableness of results, estimation, appropriate computational skills, algebraic thinking, measurement, geometry, statistics, and probability (NCSM, 1989). These critical areas are inter-related; therefore, competence in one critical area also requires competence in the other mathematics component areas.

The issues and concerns raised by the NCSM have a great impact on educators who provide instruction to mildly handicapped students. Researchers focusing on characteristics of mildly disabled adolescents have found that a majority of mildly handicapped learning disabled individuals have severe deficiencies in many academic areas, including mathematical problem solving and computation.

Cawley and Miller (1989) found that students with learning disabilities (LD) exhibited depressed achievement levels for mathematic computation and application. An examination of 220 LD children and adolescents, aged 8 to 17 years, performance on mathematical subtests of the Woodcock-Johnson Psycho-educational Battery yielded below grade level achievement for these students when compared to the grade equivalent norms of the test battery. They found that achievement levels for 17-year-old LD adolescents peaked at grade level equivalent standards of 5.8 for computation and 5.2 for applied problem solving. (see Table 1).

Lee and Hudson (1981) reported that LD adolescents also experienced significantly more difficulties in solving mathematical word problems. The investigators stated that LD subjects made more errors in reasoning, had more problems in selecting relevant information and determining the correct operational processes for solving the problem, demonstrated more instances of refusing to solve the problems, and had a greater difficulty in evaluating the correctness of their responses when compared to non learning disabled (NLD) peers. (See Table 1).

Table 1: Research - Math Ability

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Cawley & Miller (1989)	220 children from ages 8 to 17 identified as having learning disabilities.	Age levels of students.	WISC-R IQ scores, cluster scores from Woodcock-Johnson Psycho-educational Battery, and subtest scores of arithmetic computation and applied mathematics problems from WJCB.	Achievement levels at students aged 17 peaked at grade equivalent standards of 5.8 for computation and 5.2 for applied problems. Achievement levels for students aged 8-10 were at 1.0 G.E., age 11, 1.6; age 12, 2.3; age 13, 2.9; age 14, 3.4; age 15, 3.9; & age 16, 5.2. The mathematical achievement levels for LD student is linear with respect to age and that mathematical achievement slowed.
Lee & Hudson, (1981)	40 males (20 LS & 20 NLD) from junior high schools in large middle to upper-middle class suburban school district. Age ranges for LD were 12 yrs. 10 mos. to 14 yrs. 6 mos., NLD = 12 yrs. 7 mos. to 14 yrs. 3 mos. Mean IQ for LD = 96, NLD = 114.	Group membership and level of item difficulty.	There were four dependent variables: 1) adjusted mean problem-solving scores, 2) types of errors in problem-solving, 3) accuracy of monitoring answers to verbal problems, and 4) Percent of oral reading errors on the verbal problems.	Using IQ as a covariate, NLD achieved significantly higher scores than LD S's for problem solving. LD S's made more errors in reasoning, had more problems in selecting the relevant information and in determining the correct and more efficient process for correct resolution of the problem, more often refused to even attempt to solve some problems, and had greater difficulty in assessing the correctness of their responses and were frequently unable to eliminate extraneous information from a problem.

Other researchers have also stated that LD adolescents have significant deficiencies. Deshler, Schumaker, Alley, Warner, and Clark (1982) studied the conditions associated with adolescents and young adults with LD, and presented their findings across four major areas: academic achievement and ability, cognitive processing, setting demands, and academic interventions. Deshler et al. (1982) found that LD adolescents are the lowest of the low achievers. Typically, LD adolescents have very general deficits, scoring below the 10th percentile on the Reading, Written Language, and Mathematics clusters of the Woodcock Johnson Psycho-educational Battery. A majority of LD adolescents in the seventh-grade often demonstrate little growth in basic skills remediation programs, with their average reading and written language achievement scores at a high third-grade level. Reading and language skills for these children often plateau at the fifth-grade level during their senior high years. Average mathematics achievement scores for seventh-grade LD students were at the beginning fifth-grade level, with the plateauing of mathematics achievement scores at the sixth-grade level, occurring during the senior high school years. The findings indicated that LD students exhibit limited academic growth during their last 5 years of schooling.

Deshler et al. (1982) also stated that "LD adolescents are more like other low achievers than they are unlike them" (p. 3). Furthermore, Deshler and his colleagues also found that LD adolescents are deficient in study skills and strategies needed for successful performance in regular secondary classrooms, and that many LD adolescents exhibit immature executive functioning. Secondary school settings place complex demands on reading, writing, oral language, and listening skills.

The concerns presented by the NCSM, and the disappointing achievement levels of LD children and adolescents as reported by Cawley and Miller (1989), Deshler, Schumaker, Alley, Warner and Clark (1982), and Lee and Hudson (1981) clearly demonstrate the need for LD students to acquire and develop essential mathematical skills and abilities. The need for individuals to be successful in mathematics is essential for their vocational and academic advancement (Silbert, Carnine, & Stein, 1990), and the NCSM has also stated that the successful acquisition, development, and utilization of the essential skill components is necessary "for the doors to employment and further education to remain open" (1989 p. 27).

Therefore, students need instruction that is appropriate and suitable. This instruction must allow students to demonstrate and apply problem-solving and higher order thinking skills to everyday life and unique situations (NCSM, 1989).

Research and development of effective teaching methods for instructing handicapped individuals have been the goals of many in special education. Two instructional approaches that have been examined and found to be effective are direct instruction procedures and cognitively-based instructional techniques and procedures. Both approaches have demonstrated much success in teaching exceptional students mathematical word problem solving.

Direct Instruction Studies

The first approach examined is called direct instruction. Direct instruction is described as an instructional approach that joins a detailed curriculum design with effective and refined teaching techniques (Gersten, Woodward, & Darch, 1986). Direct instruction is composed of three critical components: organization of instruction, program design, and teacher presentation techniques (Carnine, Silbert, & Kameenui, 1990) and each component of the approach is sufficiently developed to provide the teacher with a detailed format for instructing students.

Proponents of direct instruction indicate that direct instruction procedures yield positive findings regarding mathematical problem solving (Carnine & Gersten, 1982; Darch, Carnine, & Gersten, 1984; Gersten & Carnine, 1984; Jones, Krouse, Feorene, & Saferstein, 1985; Wilson & Sindelar, in press). Also, it results in high allocations of academic time for mathematics instruction (Carnine & Gersten, 1982; Gersten & Carnine, 1984). Furthermore, the direct instruction method of instruction incorporates and addresses all of the components of effective teaching (Carnine & Gersten, 1982; Carnine, Silbert, & Kameenui, 1990; Gersten, Carnine, & Woodward, 1987; Gersten, Woodward, & Darch, 1986; Silbert, Carnine, & Stein, 1990).

The effectiveness of direct instruction is supported by data-based studies. Carnine and Stein (1981) demonstrated the effectiveness of direct instruction procedures when instructing preschoolers to answer correctly addition fact problems that were presented verbally and in written format. They found that preschoolers trained using direct instruction procedures exhibited significantly higher correct response rates than peers taught using rote memorization procedures (see Table 2). They also found that students taught under direct instruction procedures demonstrated significantly higher recall levels of addition facts than peers in the rote memorization condition when administered a delayed posttest.

Darch, Carnine, and Gersten (1984) found that, when taught to solve word problems through a direct instruction procedure, students deficient in word problem solving skills showed higher correct response rates on mathematical word problems than student taught using a traditional basal mathematics approach. (see Table 2). Jones, Krouse, Feorene, and Saferstein (1985), as well as Wilson and Sindelar (in press), also found that direct instruction procedures were superior to instruction using the traditional approach for teaching word problem solving found in basal mathematic programs (see Table 2).

Table 2: Research - Direct Instruction

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Carnine & Stein, (1981) Study 1	12 white, non-handicapped 4- to 6-year old preschoolers. Two groups, Group 1 mean age was 5 yrs. 6 mos., Group 2 5 yrs. 7 mos.	Direct Instruction Strategy vs. Rote Memorization Condition. S's were trained and tested individually in a quiet room for 15 min.s daily on 8 sets of addition facts.	Correct answering of addition fact problems presented verbally to S's.	Mean number of correct responses significantly higher for Direct Instruction Strategy Group than for Rote Memorization Group.
Carnine & Stein, (1981) Study 2	20 white, non-handicapped, first graders. Two groups.	Direct Instruction Strategy with instruction in an addition fact rule vs, Rote Memorization Group. S's were taught in a group for 10 min.s for 7 days.	Recall of addition facts measured daily with 18 item test. A 21-item posttest administered at the end of the last session. 4 days later a delayed posttest of 21-items was also given.	Strategy Group had been introduced to 21 facts and Memorization Group 15 facts. For immediate posttest, no significant difference between the 2 groups. For delayed posttest, Strategy Group significant difference in recalling of 15 and 21 facts. Strategy Group also finished test significantly faster than Memorization Group.
Darch, Carnine, & Gersten, (1984)	73 4th graders identified as skill deficient in solving story problems but had computational ability in 4 basic operations.	Explicit Translation Strategy (ETS) method for teaching students to solve story problems.vs. Basal method for solving problems. 2nd variable - effect of extended practice vs. fixed practice on student performance	Performance on posttest and maintenance test containing math story problems covering the 4 basic operations. Student attitude questionnaire for determining satisfaction.	Significant effect for type of instruction on posttest and significant interaction between instruction and practice. ETS S's performed better than Basal S's. ETS extended practice significantly better than non-ETS groups. ETS fixed practice no difference from other 3 groups. ETS students preferred the method for solving problems significantly more than Basal groups.

Table 2- Continued

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Jones, Krouse, Feorene, & Saferstein, (1985)	142 third grade students from 6 classes. Intact groups of 4 to 7 students from classrooms randomly assigned to either sequential or concurrent training.	Type of training students to solve word problems - sequential training vs. concurrent training of 4 basic types of story problems. S's presented with training for 9 sessions of 15 mins. in direct instruction format.	Performance on solving story problems obtained in pretest and posttest format.	Training of students to solve story problems in sequential manner better than in an unsequenced mix of story problems.
Wilson & Sindelar, (in press)	62 LD students from 9 elementary schools reading on 1.5 grade level, 80% or better on addition and subtraction skills, and in special education math program. Assigned to 1 of 3 treatment groups.	Story problem solving methods taught: Strategy plus Sequence, Sequence Only, and Strategy Only. Strategy plus Sequence, and Strategy Only scripts developed following Direct Instruction procedures, Sequence Only developed by following basal math curriculum sequences. Group instruction given during 14 thirty minute sessions.	The number of problems solved correctly was the dependent measure.	S's in Strategy plus Sequence and Strategy Only groups scored significantly higher on posttest and followup test than Sequence Only group. Significant difference between Strategy plus Sequence group and Strategy Only group on followup test.

Gersten and Carnine (1984) presented the strongest evidence regarding the effectiveness of the direct instruction approach. They reported that, when compared to other instructional program under Project Follow Through, the direct instruction mathematics program was superior to all other approaches for mathematical computation, mathematical problem solving, and overall mathematics performance on a standardized achievement test. They also stated that students in the direct instruction mathematics program showed positive outcomes on measures of self-esteem and self-concept. Gersten and Carnine also pointed out that direct instruction and behavior analysis models are effective in teaching mathematical computation skills, but direct instruction produced positive gains in problem solving while behavior analytical procedures produced negative gains.

The effectiveness of direct instruction procedures has been documented by many research investigations (Gersten, Carnine & Woodward, 1987). Thus, direct instruction should be considered as a viable method for teaching mildly handicapped individuals to solve mathematical word problems.

Cognitively-Based Approaches

The increased interest in cognitive behavior modification and metacognition in other academic skill areas by researchers, (Deshler, Schumaker, Warner, & Alley, 1981; Graham & Harris, 1989; Palinscar & Brown, 1984; Paris, Cross, & Lipson, 1984; Wong, 1985) has encouraged mathematics researchers to initiate the investigation of effective instructional procedures associated with cognitive behavior modification and metacognition (Brophy, 1986; Garofalo & Lester, 1985). Educational theorists have noted that cognitive behavior modification and metacognitive strategies hold much promise (Brophy, 1986), and that LD adolescents would benefit from systematic strategy training because they are strategy inefficient and strategy inflexible (Gerber, 1983). Brophy (1986) states that "more research and development needs to be done on methods of training students to recognize problem types and to use effective problem-solving strategies.."(p. 333).

Deshler et al. (1981) found that a series of learning strategies interventions were successful in producing positive changes in LD adolescents' performances. They also proposed that the success of a student in the learning strategies intervention program was a function of student behavioral and motivational characteristics.

Palinscar and Brown (1987) maintained that successful metacognitive instruction should include a careful analysis of the task or behavior to be demonstrated, and that identification of strategies promoting successful task completion must be made. Further, they stated that explicit instruction of these strategies must be accompanied by metacognitive information necessary for application of the strategy. Finally, the provision of feedback regarding the usefulness of the strategies, the success of the strategy acquisition, and the generalization instruction of the strategy must be included (Palinscar & Brown, 1987).

Tenets of cognitive strategy instruction has led researchers to examine various procedures specifically designed to enhance the problem solving abilities of students with learning problems. Four studies that used a cognitively based approach to instruct students to solve word problems were located. Of the four studies reviewed, two studies involved LD children and adolescents (Montague & Bos, 1986; Smith & Alley, 1981), while one used third-graders enrolled in regular elementary education classrooms (Huinker, 1989). The fourth study examined the problem solving abilities of 20 first-grade classes who had been taught by teachers using cognitively guided instruction (CGI) (Peterson, Fennema, & Carpenter, 1988/89) (see Table 3).

Two of the studies followed procedures developed by Deshler and his associates for instructing students to acquire new skills (Montague & Bos, 1986; Smith & Alley, 1981). Another study allowed teachers who had been exposed to CGI concepts to instruct students in formats complementary to the principles that they had studied (Peterson, Fennema, & Carpenter, 1988/89). The remaining study (Huinker, 1989) focused on a more formalized procedure for teaching students to solve multiplication and division word problems than the procedures implemented by CGI teachers in Peterson, Fennema, and Carpenter's (1988/89) study.

Table 3: Research - Cognitive and Cognitive Behavior Strategies

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Huinker (1989)	Twenty-six third grade students in a regular education elementary classroom participated in the study.	An instructional strategy designed to help third grade students solve multiplication and division word problems, and to understand the operations that were used.. Sessions lasted 15 minutes per day for 4 weeks.	Dependent measures were the number of correct responses and correct number sentences written.	Pre-test to post-test gains were significant . Students answered correctly 90% of the problems and wrote appropriate number equations for 89% of the items. Control group posttest scores showed students answered correctly 75% of the problems.
Montague & Bos (1986)	6 LD adolescents,age range was 15-6 to 18-2 with an average age of 16-7. Full Scale IQ ranged from 85-102 with a mean of 93.8. Reading achievement (range=4.9 to 11.4, mean grade equiv.= 7.4) and mathematics (range=5.4 to 7.2, mean grade equiv.= 6.3) from the WJPB.	An eight-step strategy designed to assist high school students to read, understand, solve, and check verbal mathematical problems encountered in general mathematics curriculum. Subjects received instruction in the strategy daily for 50 minutes.	Percentage correct on selected 2-step verbal math problems which included all of the 4 basic mathematical operations.	The results of a visual analysis of the data showed that 5 of the 6 participants made substantial progress after receiving the cognitive strategy training. All subjects, except for 1, demonstrated an increase of five to six correct responses during the treatment phase. Of the 6 subjects, 4 reached the criterion established for generalization of the strategy to three-step word problems.

Table 3 - Continued

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Peterson, Fennema, & Carpenter (1988/89)	40 first grade teachers randomly assigned to 2 groups (CGI & Control)	Cognitively Guided Instruction. Principles of CGI was delivered to teachers during a 4 week summer workshop. No specific techniques were taught to participants.	Systematic observations and anecdotal data were collected on the instructional procedures implemented by S's. Also posttest scores of students on ITBS were collected.	CGI teachers gave more opportunities for students to solve word problems and more often expected students to use multiple strategies. CGI teachers also often began a lesson by recounting a story and them presented students with a word problem based upon the story. Comparisons between students in classes of CGI and Control teachers resulted in CGI classes exhibiting significantly greater ability to solve addition, subtraction, and complex word problems.
Smith & Alley, (1981)	3 LD sixth graders, with below average to average IQ scores, Math grade levels 3.2 to 4.6..	A 7 step cognitive behaviorally based problem solving strategy. Successively implemented with S's with a multiple baseline design format.	Percent correct on solving of word problems.	Overall average gain of S's was a 75.4% correct responses in solving 8 problems. S's exhibited significant learning rate for learning the strategy, average of 2.6 days.

While all studies reported success in the performance of students to solve word problems, the modes of presentation of word problem solving were very different. Montague and Bos (1986) used a highly structured direct instruction format combined with cognitive principles. Huinker (1989) and Smith and Alley (1981) used a less structured instruction whereas, CGI teachers (Peterson, Fennema, & Carpenter, 1988/89) implemented loosely structured cognitive problem solving procedures.

While Peterson, Fennema, and Carpenter's study appeared to be loosely implemented, they did offer suggestions as to how CGI can be implemented. They suggested that teachers should (a) use problem solving activities as the basis for teaching addition and subtraction, (b) be aware of the different type of word problems and be cognizant of the processes that children use to solve different types of word problems, (c) be able to assess whether a child can solve a word problem and also how the child solves the problem, (d) use the knowledge gained about how the child solves problems to design appropriate instruction, and (e) ensure that mathematics instruction stresses the relationships among skills, concepts and problem solving.

Of the four studies reviewed, only one study appeared to address the issue of generalization (Montague & Bos, 1986). They reported that 4 of the 6 subjects were able to generalize the strategy to three-step word problems.

A majority of the researchers appeared to subscribe to Goldman's (1989) proposition that LD students need to be taught strategies that would assist them in adequately representing the problem (Huinker, 1989; Montague & Bos, 1986; Smith & Alley, 1981), planning for solving the problem (Huinker, 1989; Montague & Bos, 1986; Smith & Alley, 1981), carrying out computational operations (Huinker, 1989; Montague & Bos, 1986; Smith & Alley, 1981), and evaluate the successful implementation of the other problem solving stages (Montague & Bos, 1986; Smith & Alley, 1981). Huinker (1989), Montague and Bos (1986), and Smith and Alley (1981) also adhered to Goldman's contention (1989) that mathematics strategy instruction should be task-specific, but only Montague and Bos (1986) included generalization instruction.

While the aforementioned cognitive procedures provide researchers with a solid foundation for developing and implementing procedures and techniques for increasing correct response patterns for solving mathematical word problems among students, it should not be accepted as the only acceptable mode of instruction. Another cognitively based instructional approach also may prove to be beneficial in assisting students in learning how to solve mathematical word problems. The following section addresses mnemonic instruction.

Mnemonic Instruction

An area of investigation related to the cognitively-based strategy approaches for problem solving is the use of mnemonic instruction in assisting students to acquire skills and content information. In the five studies reviewed (see Table 4), a majority of the researchers used mnemonic techniques to help students acquire knowledge and content information (Condus, Marshall, & Miller, 1986; Mastropieri, Scruggs, & Levin, 1985; McLoone, Scruggs, Mastropieri, & Zucker, 1986; Scruggs & Mastropieri, 1989). In one study, Machida and Carlson (1984) examined the role of mnemonics in mathematics instruction with Japanese students.

The research conducted by Mastropieri and her associates (1985, 1989, 1990), as well as Condus et al. (1986) indicates that mnemonic instruction is effective in assisting LD students to exhibit significant positive performances on recall information tasks. These researchers have also demonstrated that the information learned under mnemonic conditions is retained over long periods of time (see Table 4).

Machida and Carlson (1984) demonstrated the effectiveness of the use of verbal mnemonic rhymes for teaching 100 seventh grade Japanese junior high school students to solve algebraic problems involving monomials, polynomials, and equality-inequality concepts. The researchers used a technique developed by the Nakane Institute for the teaching of mathematics and reported that subjects taught

Table 4: Research - Mnemonics

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Condus, Marshall, & Miller, (1986)	64 students identified as LD, 12 years old. S's classified as having high or low receptive vocabularys assigned randomly to one of four conditions.	3 specific methods: Keyword-Image, Picture Context, Sentence-Experience Context for vocabulary development; 5 week period; 3 sessions per week, 20 minutes each.	Recall performance on multiple choice test. administered 4 times. Pretest, posttest, maintenace, & follow-up tests.	Students in the keyword condition did better across time than student in other groups. Low ability students in keyword condition outperformed students with high and low receptive vocabularies assigned to the other conditions.
Machida & Carlson, (1984)	100 12- and 13- year old 7th graders from 2 Japanese junior high schools.	Verbal mnemonic rhymes developed for teaching algebra. Instruction was for 5 weeks, 4 hours per week.. 5 minutes per period used for mnemonic instruction.	Pretest, and two posttests measured ability to solve algebra problems. Tests given before and after instruction. Second posttest given 2 weeks after instruction was completed.	Experimental treatment was reported to be significantly effective on both posttest measures. Verbal mnemonic rhymes facilitated learning and retention of mathematical computation and problem solving skills.
Mastropieri, Scruggs, & Levin, (1985) Study 1	90 9th grade LD students. WISC-R IQ - 95, SD = 10 (range 72 to 129). Two achievement groups (high & low) based on CAT reading comprehension subtest.	Three conditions: mnemonics, questioning, and free study conditions. Experimenter worked with S's for 21 minutes. Prepared scripts.	Recall of information learned. Response latency: time between the end of question and beginning of relevant response. Student self-report of strategies.	Mnemonic condition S's significantly correctly recalled information better, took more time in responding, and implemented significantly more effective recall strategies (77%) than the other groups (2% & 1%). No significant difference between questioning and free study groups on dependent measures

Table 4- Continued

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Mastropieri, Scruggs, & Levin, (1985) Study 2	45 7th grade non-LD students. Reading achievement levels comparable to higher achievement group of Study 1.	Identically same independent variables examined as in Study 1 and identical procedures.	Identical dependent measures as in Study 1.	Results similar to Study 1 with 89% implementing more effective recall questioning and free study groups used a rote rehearsal strategy mode.
McLoone, Scruggs, & Mastropieri, & Zucker, (1986)	30 7th grade and 30 8th grade LD students. WISC-R scores 83 to 128 (Mean = 96.22, SD = 8.36)	Two conditions: mnemonic strategy training & transfer,and direct rehearsal training & transfer conditions. Individual training & transfer tasks given in 1 session (approx. 25 min.).	Oral responses to 14 item test measured S's recall of definitions learned. Strategies employed by S's were observed and classified into 1 of 4 categories: no strategy, rehearsal, ineffective, & effective strategy usage.	Recall performance and transfer of task, S's in mnemonic condition significantly better than S's in directed rehearsal (DR) condition. Effective strategy use in 91% of cases observed in mnemonic S's. Rehearsal strategy use in 100% of instances by S's in DR condition.
Scruggs & Mastropieri, (1989)	26 7th & 8th grade LD students from inner-city school. 20 used in analysis. Mean age = 13 yrs. 8 mos.. WRAT reading grade equivalent 4.96 , math grade equivalent 5.84 in 3 classes.	Application of adapted academic content with inclusion of mnemonic instruction compared to traditional textbook-based instruction. Classes covered a chapter every 2 weeks.	20-30-item multiple choice test given at end of each chapter presentation. Teacher's perception of appropriateness of traditional and mnemonic instruction for each student.	S's under mnemonic instruction significantly higher percentages of correct responses and higher grades than under traditional instruction condition. Teacher rated mnemonic material as more appropriate for content-area instruction of LD students. Teacher reported that students were more motivated, engaged in more class discussions, & enjoyed the materials under the mnemonic condition.

under the verbal mnemonic condition performed significantly better than subjects taught without the benefit of the verbal mnemonic instruction on posttests administered immediately following the end of instruction, and 2 weeks after instruction had ended. Machida and Carlson (1984) propose that the verbal mnemonic rhymes facilitated the acquisition and retention of computational and problem solving skills when applied to the algebraic concepts (see Table 4).

Scruggs and Mastropieri (1990) stated that mnemonic instructional procedures have resulted in consistent and positive outcomes for students, have a large impact on recall, comprehension, and affective outcomes of students, and have been positively received by teachers and students. They further indicated that teachers can successfully develop mnemonic instructional materials.

Pressley, Scruggs, and Mastropieri (1989) stated that because LD students do not generally and appropriately use elaborate strategies to enhance recall, instructional procedures should be developed to provide these students with skills to improve and enhance their recall. Pressley et al. (1989) suggested that LD students may benefit from classrooms adapted to include effective cognitively based learning strategies, and that mnemonic instruction is an effective cognitively based strategy that LD students can be taught to use and experience improved learning.

The use of mnemonics has been shown to be effective in assisting students to learn and recall reading and non-mathematical content information (Condus, Marshall, & Miller, 1986; Mastropieri, Scruggs, & Levin, 1985; McLoone, Scruggs, Mastropieri, & Zucker, 1986; Scruggs & Mastropieri, 1989, 1990), but it has also been demonstrated that mnemonic instructional procedures can also facilitate the acquisition of mathematical concepts (Machida & Carlson, 1984). Mnemonic instructional procedures in teaching mathematical skills and concepts deserves to be further researched as a viable means for assisting students in learning cognitively based procedures for solving mathematical word problems.

Cognitively based mathematics instructional procedures for solving word problems and mnemonic instructional procedures for recalling content information have been reported to be effective with mildly handicapped and non-handicapped individuals. These effective procedures have also neglected, on the whole, Pressley's five principles of mathematics instruction : (1) teach strategies, (2) teach specific strategy knowledge, (3) teach general strategy knowledge and general strategies, (4) enrich the knowledge base, and (5) practice each component and coordinate the components (1986).

Pressley (1986) stated that instructional procedures should teach students to utilize strategies associated with specific cognitive goals, monitoring strategies, and higher order strategies. He (1986) also stated that students should be taught when, where, and how to apply strategies, understand and recognize the situations that promote efficient and effective functioning of specific strategies.

Furthermore, Pressley further indicated that students should be provided with foundational knowledge that serve as prerequisite elements and operations for strategic implementation. Finally, he stated that students need to be given situations in which they can practice a single strategy in multiple settings as well as in combination with other learned strategies.

The last principle that Pressley alluded to focuses on providing students with practicing a strategy in multiple situations. This principle dealt with the generalization of strategic skills by individuals across settings.

Review of Generalization Literature

The next group of studies reviewed deal with generalization as applied by researchers associated with the Institute for Research in Learning Disabilities at the University of Kansas (KU-IRLD). These researchers have developed and followed generalization procedures based upon techniques suggested by Stokes and Baer (1977) and have instituted them in their Learning Strategies Curriculum (Lenz, Schumaker, Deshler, & Beals, 1984; Nagel, Schumaker, & Deshler, (1986; Schumaker & Sheldon, 1985). These suggested techniques are to (a) teach LD students to cue others for reinforcement, (b) use sufficient and diverse exemplars, (c) train loosely, (d) use a variety of agents, setting, and conditions, (e) use delayed and intermittent reinforcers, and (f) tell students to generalize (Deshler, Alley, Warner, & Schumaker, 1981).

Schmidt and his associates (Schmidt, 1984; Schmidt, Deshler, Schumaker,& Alley, 1987) investigated the effects of four generalization procedures developed by the KU-IRLD (see Table 5). These procedures consisted of acquisition of the strategy, review of the steps of the strategy, transfer activities instituted by strategy teachers, and self-control activities undertaken by the student. These procedures were examined across four task-specific writing strategies (sentence writing, paragraph writing, error monitoring, and theme writing). Each type of generalization procedure was implemented sequentially if the subjects failed to demonstrate mastery of skills in regular education classrooms. Although Schmidt and his colleagues reported positive results on the subjects' writing performances, the first generalization procedures (acquisition) proved to be ineffective in promoting generalization. They found that after implementing the review and transfer activities generalization procedures, more than half of the students were able to successfully implement the strategies in their regular education classrooms. Schmidt and his associates (1984; 1987) also indicated that the transfer activities generalization procedure was the most powerful implementation plan.

Beals (1985) examined the effects of teaching two reading strategies (paraphrasing and self-questioning) and two writing strategies (sentence writing and error monitoring) to learning disabled (LD) and non-learning disabled (NLD) students in a large

Table 5: Research - Generalization Studies

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Beals (1985)	27 students, 9 LD, 9 low achieving (LA), 9 high achieving (HA) in 3 regular education classes; 3 of each type per classroom.	Effect of teaching 2 reading and 2 writing strategies in large group instructional format.	Performance and observational data on sentence writing, error monitoring, self-questioning & paraphrasing strategies.	All three types of students can learn the specific reading and writing strategies under large group instructional formats. LD and LA students had difficulty maintaining the skill once instruction ended.
Ellis (1985)	13 LD high school students who had learned at least 2 strategies from KU-IRLD's Learning Strategies program.	Procedure designed to enhance student's role as control agents of their own strategic functioning. Pretest & posttest information was also obtained.	Performance data on each of the stages of the procedure, students' weekly academic performance in regular classrooms, and teachers' perceptions of students' classwork.	Students were able to generate their own strategies to improve their academic performance in targeted classes, for non-targeted classes no significant improvement noted.
Schmidt (1984); Schmidt, Deshler, Schumaker, & Alley (1987)	7 mainstreamed LD high school students (English and social studies). Mean age 15.8 yrs. Mean grade placement = 10.2.. Mean WISC-R IQ - 95 (range 89-110).	4 generalization procedures (acquisition, review, transfer, & self-control) implemented sequentially if S's failed to demonstrate mastery of 4 specific writing strategies learned in regular education classrooms.	4 dependent measures: S's semester grades in regular classes; S's Written Language Subtest scores on the WJPB Part 2; teacher and student satisfaction on written products; and performance on district's 11th grade writing competency examination.	Significant improvement on Written Language test; S's grade point averages in English and social studies improved from 2.1 before training to 2.7 on a 4.0 grade scale; mainstream teachers' were satified withe the improvements in written expression; S's performance on the competency examination was within the average range of scores for regular education students for the same examination.

group instructional format. Strategies were taught in two classes and a third classroom served as a comparison group. Beals found that all types of students were able to learn the strategies under large group instruction formats, but also noted that LD and low achieving NLD students had difficulty maintaining the skills learned once instruction ended (see Table 5).

Ellis (1985) examined the effects of a executive monitoring strategy designed to enhance the students' role for controlling their own strategic functioning. Ellis reported that students were able to generalize the steps of the strategy in developing their own strategies that resulted in improved academic performance in specifically targeted classrooms. Ellis indicated that the generalization procedures instituted with the executive monitoring strategy was effective in enhancing student success (see Table 5).

Ellis, Lenz, and Sabornie (1987a) also reviewed all of the aforementioned studies and concluded that students need to be explicitly instructed to generalize the use of strategies that they have learned. They further indicated that teachers should be expected to explicitly exhibit confidence that students will be able to generalize skills and strategies to different situations and settings, and continual feedback to the student regarding the student's progress toward generalization is essential.

While Ellis, Lenz, and Sabornie (1987b), Deshler et al. (1981) proposed that their procedures are effective in promoting generalization of task-specific and executive monitoring strategies, they fail to accommodate and investigate generalization propositions held by Rosenbaum and Drabman (1979). Rosenbaum and Drabman (1979) proposed that for students to manage themselves behaviorally, students need to be taught procedures to observe and monitor their behaviors, and externally managed contingencies need to be delivered to reinforce effective behaviors. Furthermore, they indicated that transfer of the contingency management to the student needs to be a gradual process, accompanied by instructions and cues to assist the student in exhibiting appropriate behaviors, and that programmed contingencies need to be gradually withdrawn.

Ellis et al. (1987b) and Deshler et al. (1981) have also deviated from the effective format utilizing direct instruction procedures contained in the acquisition stages of their strategy programs. The generalization procedures are not as tightly structured and afford the strategies teacher with a great deal of latitude, in which ineffective instruction may occur. The generalization procedures do not appear to follow effective teaching formats and may cause problems for teachers who have adopted a philosophy of direct instruction.

Review of Problem Solving Methods

In looking specifically at the problem solving component, mathematic educators have proposed that metacognitive techniques are needed to provide students with the essentials of problem solving skills. Many mathematicians have adopted the position presented by

Polya for the teaching of problem solving. Polya (1957) has proposed that for individuals to solve elementary word problems, a four-step method should be implemented: (a) understanding the problem, (b) devising a plan for solving the problem, (c) implementing the plan, and (d) looking back at the plan to determine whether the solution could have been obtained through alternate routes. Polya determined that the last step, looking back at the plan, was the most critical step of the problem solving process.

Garofalo and Lester (1985) elaborated on Polya's four-phase model for problem solving. They proposed that there are four categories of specific activities that are undertaken when solving mathematical problems: orientation, organization, execution, and verification.

The orientation category refered to strategic behaviors exhibited for assessing and understanding a problem. Within this category, Garofalo and Lester included comprehension strategies, analysis of information and conditions tasks, behaviors associated with assessing the familiarity of the task presented, the initial and subsequent representation of the demands of the task, and the assessment of the difficulty levels of tasks and of the chances of successful solution of the task activities (1985). Goldman (1989) further clarified Garofalo and Lester's description of orientation by describing it as the strategic behaviors developed to assist the individual to arrive at an understanding of the problem.

The organization category included strategies that involve the planning of problem solving solutions and the choice of solutions selected by the individual. Garofalo and Lester (1985) stated that three components are incorporated in the organization category: the identification of goals and subgoals, global planning, and local planning to implement global plans.

The execution category is described by Garofalo and Lester as being composed of activities designed to regulate the behaviors of the individual so as to conform to the plans set forth by the organization category (1985). The subcomponents of this category included performance of local actions, monitoring of progress of local and global plans, and the use of trade-off decisions (i.e. speed vs. accuracy, the degree of elegance of the solution). Goldman (1989) described the elements of the execution category as the actual components that constitute the process of doing computational mathematics.

Garofalo and Lester's last category, verification, consisted of the evaluation of the decisions made by the individual, and of the outcomes of the executed plans. These decisions are evaluated across the areas of orientation, organization, and execution. Orientation decisions focused on the adequacy of representing the problem. Organizational decisions dealt with the consistency of local plans with global plans, and global plans with the goals of the individual. Execution decisions focused on the adequacy of the performance of the actions undertaken by the problem solver, and the consistency of the actions with plans, local results with plans and problem conditions, and the final results with problem conditions (Garofalo & Lester, 1985).

These categories of problem solving presented by Polya, and Garofalo and Lester have allowed mathematic educators and researchers to examine the various approaches for facilitating the solving of mathematical story problems. Many researchers and educators interested in mathematical word problem solving methods have adopted the categories proposed by Polya and Garofalo and Lester (see Table 6).

Kennedy and Tipps (1988) indicated that there is a wide variety of techniques that students can use to solve mathematic word problems. These investigators suggested that students look for patterns, draw a diagram or picture, make a model, construct tables or graphs, guess and check the answer, account for all possible logical answers, act out the problem, write the problem in a mathematical sentence, dissect the problem into smaller pieces, restate the problem, identify necessary information given in the problems, and change the point of view in which the student attacks the problem.

The current state of research in mathematical word problems solving approaches indicates that teachers need to focus on instructing students to approach problem solving systematically.

Table 6: Comparison of Methods following Polya's and Garofalo & Lester's 4-step methods for solving mathematical word problems

Polya (1957)	1	2	2	2	2	2	1	1	3	3	4
	Read	Underline Numbers	Identify keywords	Draw Picture	Draw Tables	Draw Charts	Reread problem	Observe drawing	Write equation	Compute answer	Check answer
Talton (1988)	√								√	√	√
Smith & Alley (1981)	√		√				√		√	√	√
Yancey, et al. (1989)				√	√	√			√	√	√
Lee (1982)	√		√	√	√	√				√	√
Nuzum (1987)	√		√	√	√	√	√	√		√	√
Huinker (1989)			√	√	√	√			√	√	
Ross, et al. (1988)	√								√	√	
Charles & Lester (1984)	√	√	√	√	√	√			√	√	√
Montague & Bos (1986)	√	√	√	√	√	√			√	√	√
Darch, et al. (1984)	√		√						√		
Jones, et al. (1985)	√								√	√	√
Garofalo & Lester (1985)	A	B	B	B	B	B	B	C	C	C	D

Key to Polya and Garofalo & Lester's methods

Polya	Garofalo & Lester
1 = Understanding the problem. 2 = Devising a plan for solving the problem. 3 = Implementing the plan. 4 = Looking back at the plan.	A = Orientation to the problem B = Organization of information given. C = Execution of calculating answer. D = Verification of solution and plan.

There appears to be agreement among experts in the field of mathematics instruction that the adoption, internalization, and implementation of logical problem solving plans are essential for students to achieve success in solving mathematical word problems.

Examination of Specific Components Dealing with Mathematical Word Problem Solving

Although many researchers have adopted the approaches proposed by Polya (1957) and Garofalo and Lester (1985), other research has been conducted to examine the numerous variables that facilitate the solving of mathematical story problems. These variables include the selection of key words by problem solvers (Blankenship & Lovitt, 1976; Cawley, Miller & School, 1987; Cruickshank, 1948; Englert, Culatta, & Horn, 1987; Goodstein, Bessart, Thibodeau, Vitello, & Vlahakos, 1972; Goodstein, Cawley, Gordon, & Helfgott, 1971; Nesher & Teubal, 1975; Smith & Alley, 1981) and the graphical representation of word problems (Bolduc, 1970; Lee, 1982; Neil, 1969; Portis, 1973;Threadgill-Sowder & Sowder, 1982; Yancey, Thompson, & Yancey, 1989). Research related to these variables is presented.

Necessity of Key Word Method

Two components that many researchers have investigated are the inclusion of extraneous information in mathematical word problems (Blankenship & Lovitt, 1976; Cawley, Miller & School, 1987;

Cruickshank, 1948; Englert, Culatta, & Horn, 1987; Goodstein, Bessart, Thibodeau, Vitello, & Vlahakos, 1972; Goodstein, Cawley, Gordon, & Helfgott, 1971) and the instructing of students to identify critical "cue words" (Nesher & Teubal, 1975; Smith & Alley, 1981). A review of research examining the presence of extraneous information in mathematical word problems is initially presented.

The investigation of extraneous information in mathematical word problems, and the relationship of such information has been studied extensively. Cruickshank (1948) compared the problem solving abilities of mentally retarded and non-retarded boys of similar mental ages on a series of mathematical word problems containing extraneous information. Cruickshank (1948) found that mentally retarded subjects experienced greater difficulty in solving mathematical word problems that contained extraneous numbers than the non-retarded control group (see Table 7).

Goodstein, Cawley, Gordon, and Helfgott (1971) investigated the effects of extraneous information on the problem-solving abilities of educable mentally handicapped (EMH) children. Sixty-two educable mentally handicapped subjects were selected for the study and divided into two equal groups of 31 subjects per group. The two groups were presented with a set of mathematical word problems with some of the problems containing extraneous, unnecessary information. Based upon the analysis of the data obtained, Goodstein et al. (1971) concluded that extraneous information severely impeded

Table 7: Research - Key Word Identification

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Blankenship & Lovitt (1976)	7 boys with an age range of 9 to 12 years, receiving services in a special class. Students were of normal intelligence but were at least 1 year below their peers in reading and mathematical achievement.	Effect of manipulating word problem vocabulary on accuracy and speed.	Performance on worksheets containing 12 different types of word problems. Manipulations included : varying number/types of nouns, type/tense of verbs, introductory sentence, the form of the written question, presence/placement of extraneous information, numeral presentation mode, and verbal cue form of type of operation needed.	S's performed poorer and solved less problems once extraneous information was included. Other variables associated with verbal word problems did not affect speed or accuracy.
Cawley, Miller, & School, (1987)	63 LD middle and high school students. CA mean = 14.4, range 10-21; IQ mean = 98.55, range 79-128; Reading G.E.. mean = 6.44, range 2.0-14.0; Math G.E. mean = 5.35, range .0 -9.4.	Effect 3 of problem types: (Direct vs Indirect questions; Nonextraneous vs. extraneous information, and addition vs. subtraction word problems) on performance.	Total number of problems correctly solved by S's.	Indirect problems more difficult than direct problems; problems with extraneous information more difficult to solve than problems without extraneous information; when grouped by operation needed to solve the problem, indirect addition and subtraction problems were more difficult to solve, and subtraction problems were easier to solve than addition problems.

Table 7- Continued

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Cruickshank (1948)	2 groups of 15 males each. Experimental Group - IQ= 73.33, CA = 14.29, MA = 10.06, Arithmetic Age = 9.73; Control Group - IQ = 110.4, CA = 9.09, MA = 9.96, Arithmetic Age = 9.84.	Ability of mentally retarded and non-retarded males to identify relevant facts needed for solving verbal word problems.	Number of correct responses on a series of 3 sets of word problems containing varying degrees of extraneous information.	MR students not as skilled as non-retarded subjects in differentiating unnecessary information from necessary information.
Englert, Culatta, & Horn (1982)	Students (n=48) who were able to achieve 90% or better on the addition of numbers with sums less than 10 were selected. Two groups: 2nd grade (12 LD, 12 non LD), 4th grade (12 LD, 12 non LD).	The effects of four types word problems: no irrelevant information (NI), linguistic distractors (L), irrelevant subjects (IS), and irrelevant object quantities (IO)] on student performance.	Data collected on the accuracy and the rate at which students solved the problems.	LD students were less accurate (68%), NH peers (80%)..The IO problem type was significantly more difficult to solve than IS problems, and both were significantly more difficult than NI problems. LD students less accurate with problems containing irrelevant information. No significant differences in performance between LD and NH peers on problem type.
Goodstein, Cawley, Gordon, & Helfgott, (1971).	62 EMH subjects divided into two equal groups on the basis of IQ. Low: mean IQ 57.77, grade reading level= 2.26 , and CA mean =12 yrs. 3 mos. . High: mean IQ = 74.55 , reading 2.71 (SD = .81) for, and CA = 12 yrs. 7 mos.	The effects of extraneous information on the problem-solving abilities of educable mentally handicapped (EMH) children	Percent of correct performance by the two groups on a set of mathematical word problems. Some of the word problems contained extraneous, unnecessary information.	A significant main effect for the presence of extraneous information in the word problems (F = 99.50, 1,60 *df*, *p* , .001). and a significant interaction between the IQ level of the groups and the presence of extraneous information (F = 4.12, 1,60 *df*, *p* , .05)

Table 7- Continued

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Goodstein, Bessart, Thibodeau, Vitello, & Vlahakos, (1972)	18 EMH subjects participated in the study and were divided into three equal groups on the basis of their MA.	Three variables: presence of extraneous information, supraordinate set language, and the use of pictures as problem solving aids upon the verbal problem solving behavior.	Numbers of correct problems computed by S's for each of 5 conditions.	Significant main effect for MA, Picture condition and for comparison between picture conditions. No significant main effects due to set language or inclusion of extraneous written information. Significant differences between no picture exact information conditions, and no picture and qualitative distractor conditions. Relationship between the effect of the use of pictures and 3 levels of mental age yielded significant results.
Nesher & Teubal, (1975) Study 1	397 fifth and sixth graders from school in Jerusalem, Israel. 177 S's in "neutral' problem group, 270 S's in "critical" problem group.	Effect of key words on choice of operation for solving addition and subtraction word problems.	Worksheet allowed S's 2 possible methods for solving problems on the worksheet. S's choice of mathematical operation performed was recorded.	Results indicated that there was an association between keyword (buying) with addition, and keyword (losing) with subtraction. When S's were presented with a 'neutral" problem, a preference to add was exhibited.
Nesher & Teubal, (1975) Study 2	Boys and girls at the end of 1st grade year.	Effect of keywords (more/less) on the mathematical operation required to solve word problems.	Dependent measure was the choice of operation used by S's to solve the word problem.	Results also revealed that there was a significant association between the verbal cue and the choice of correct operation needed.
Smith & Alley, (1981)	3 LD sixth graders, below average/average IQ scores, Math grade levels 3.2 to 4.6.	Cognitive behaviorally based problem solving strategy. Successively implemented with S's with a multiple baseline design format.	Percent correct on solving of word problems.	Overall average gain of S's was a 75.4% correct responses in solving 8 problems. S's exhibited significant learning rate for learning the strategy, average of 2.6 days.

the resolution of mathematical word problems by EMH children (see Table 7).

Further investigation of the effect of extraneous information was examined by Goodstein and his associates. Goodstein, Bessart, Thibodeau, Vitello, and Vlahakos (1972) investigated the effects of three variables: the presence of extraneous information, supraordinate set language, and the utilization of pictures as problem solving aids upon the verbal problem solving behavior of EMH subjects at 3 Mental Age (MA) levels. The researchers developed 100 word problems that involved the addition of numbers with sums less than 10. Of the 100 word problems, 50 problems were written to include identical set language (i.e., dogs = the number of dogs to be calculated) and 50 problems were written to include supraordinate set language (i.e., dogs and cats = the number of animals to be calculated). Five types of conditions involving pictures as problem solving aids were also developed. These problems were then given to the subjects to solve and the data were analyzed. A significant main effect was found for MA (F= 5.15, 2,15 *df*, $p < .05$). When the means for the three groups were compared using the Newman-Keuls procedure, the MA-7 group was found to be significantly lower than both the MA-8 and MA-9 groups. There were no significant main effects due to the set language or for the inclusion of the extraneous written information. A significant main effect was observed by the researchers for Picture condition (F = 9.14, 4,60 *df*,

$p < .01$) and when a comparison between the picture conditions were made, significant differences were found between the no picture condition and the condition containing the exact information (Condition 2), and the no picture condition and the condition that included the qualitative distractor (Goodstein et al.,1972).

A significant interaction was also observed between mental age and the Picture Conditions (F= 2.22, 8,60 *df* , $p < .05$). Further investigations also revealed significant effects between MA and the No Pictures condition (F = 18.80, 2,10 *df* , $p < .01$); the MA and Quantitative Distractor condition (F = 17.80, 2,10 *df* , $p < .01$), and MA and the combined Qualitative/Quantitative condition (F = 10.18, 2,10 *df* , $p < .01$). The investigation of the relationship between the effect of the use of pictures and the three levels of mental age also yielded significant results (see Table 7). In summary, these results indicate that the presence of pictures was helpful in assisting subjects to solve the word problems, and that the inclusion of extraneous distractors affected the performance of the subjects on the solving of word problems.

Blankenship and Lovitt (1976) examined the techniques of rereading the problem, writing out the problem, and reexamining the solution obtained by the students. Word problems were developed by varying the number and types of nouns used in the problems (Class 1, 2 and 7 problems), the type or tense of verb (Class 9 and 12 problems), the presence of an introductory sentence

(Class 3 problems), the presence and placement of extraneous information in the word problem (Class 4, 5, and 6 problems), the form of the question asked by the problem (Class 10 problems), the mode of numeral presentation in the word problem (Class 11 problems), and the form of the verbal cue to the kind of operation that was needed to solve the word problem (Class 8 problems) and were presented to the subjects.

At the end of the study, the data were analyzed and a comparison of total mean baseline performance to performance in each class of problems was conducted. Blankenship and Lovitt (1976) found that the presence of extraneous information in word problems resulted in decreased accuracy and computational speed (see Table 7).

In a related investigation by Englert, Culatta, and Horn (1987), the effects of four problem types containing irrelevant information on the performance of learning disabled students (LD) and their normal achieving grade-age non-handicapped peers (NH) was examined. The four problem types included word problems with no irrelevant information (NI), word problems with linguistic distractors (L), word problems with irrelevant subjects (IS), and word problems with irrelevant object quantities (IO). Data were collected on the accuracy of the students on the word problems, and the rate at which students solved the problems.

The data were analyzed and a significant main effect was exhibited between the problem type and the groups of students tested.

When group means were compared, LD students were less accurate than non-handicapped peers. LD students achieved accuracy rates averaging 68%, while non-handicapped peers averaged 80% accuracy levels. When problem types were compared, the IO problem type was significantly more difficult to solve than IS problems, and both were significantly more difficult to solve than NI problems. There were no significant differences when the performance of LD students was compared to NH peers on all types of problems (see Table 7).

A more recent investigation by Cawley, Miller, and School (1987) examined the effect of problem type on the performance of LD adolescents. They investigated three levels of problems (direct vs. indirect questioning, nonextraneous vs. extraneous information, and addition vs. subtraction word problems). They reported that indirect questioning addition and subtraction problems, and problems containing extraneous information were more difficult to solve (See Table 7). They also reported that subtraction problems were the easiest for the subjects to solve.

In addition to examining research on inclusion of extraneous information, research on instructing students to identify specific keywords for problem resolution was also examined. Smith and Alley (1981) used a 7-step instructional procedure for teaching LD students to solve mathematical word problems successfully. The procedure followed the learning strategies approach (Alley &

Deshler, 1979) and required the student to read the problem, reread the problem, use objects to show the problem, write the problem, work the problem, check the solution, and to show the complete answer. One step of the strategy instructed students to identify "cue words". As noted previously, Smith and Alley (1981) found the strategy to be effective in solving mathematical word problems (see Table 7).

Nesher and Teubal (1975) conducted two investigations examining the effects of keywords on students' choice of mathematical operations required for solving addition and subtraction word problems. They concluded that certain keywords have an influence on the specific mathematical operation chosen by students for solving word problems, but that some of these keywords can also serve as distractors resulting in the incorrect resolution of the word problem. Nesher and Teubal (1975) further indicate that instructing students to cue into key words does not ensure the selection of the correct mathematical operation (see Table 7).

The procedures for teaching students to look for specific keywords has been advocated by many mathematics educators as being ineffective (Mahlios, 1988; Nuzum, 1987), and are instances of negative learning (Cawley, 1984b), and may result in the incorrect resolution of the problem (Sowder, 1989).

Cawley (1985) stated that teaching students to cue on specific words encourages students to bypass the information set presented in the problem. He asserted that because mathematical word problems are problems in which words, the attributes of the words, and the structure of the words are used to create word problems, and that word problems are not computational tasks embedded in words (Cawley, 1985). Therefore, he stated that an individual must be able to analyze and interpret the information in the problem so that decisions can be made about how to solve the problem.

The six studies in which the inclusion of extraneous information into word problems was examined, provide support for the idea that students need to be instructed to determine what constitutes the key words and key informational elements that are needed to solve mathematical word problems (Cawley, 1984b; Cawley, 1985; Nuzum, 1987). While the studies did not specifically address the terms "key words", the ability of students to select and use relevant information for word problems, and consequently solve the problems, present a strong argument for the instruction of the "Key Word" method for the solving of mathematical word problems. The results from these studies enable the investigators to validate the procedures that are commonly taught in elementary and secondary mathematics classrooms. Procedures that do not stress the importance of students to look for key words, important information and to understand the information when attempting to solve word problems does not promote competency in problem solving (Nuzum, 1987).

Necessity of Graphic Representation

In addition to focusing on the inclusion of extraneous information, other researchers have focused on the types of formats that may enhance the ability of individuals to solve mathematical word problems. Researchers have investigated the effects of verbal formats for solving word problems and have compared these effects to non-verbal or drawn word problem solving formats.

Research in these two formats of mathematical word problems have been conducted in two specific situations: testing situations and instructional sessions. It has been shown by some researchers that without prior instruction, individuals have been more successful in correctly answering problems that were presented in a pictorial or diagramed format than in verbal format (Bolduc, 1970; Neil, 1969; and Portis, 1973) (see Table 8).

Although there has been considerable research into the use of drawn formats for testing situations, there have been few studies that have examined the drawn format verses the verbal format for instructional settings. Threadgill-Sowder and Sowder (1982) investigated the effect on performance of students presented with a verbal format compared to a drawn format. Aptitude measures used in the study were all adaptations of the French Kit of Cognitive Factors and were used to determine if there were any differences between test score performances for students who practiced on problems in the verbal format and those who had practiced the same

Table 8: Research - Graphic Representation

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Bolduc (1969)	36 first grade students from 3 schools. Randomly assigned to 4 treatment groups.	Effects of: 1) Question position within word problem; 2) Same vs. different names elements within problems; & 3) Presentation mode - with visual aids (VA) :direct representation, indirect, & no VA..	Number of problems answered correctly by S's. Test developed by examiner with KR-20 reliability coefficient of .65.	No significant differences between the 2 levels of Factor 1 and Factor 2. Significant differences among 3 levels of Factor 3, with problems without a visual aid being more difficult. No significant differences between problems with visual aid representations.
Lee (1982)	16 fourth grade students, 8 girls, 8 boys from a rural elementary school. Two groups.	Use of specific heuristics to increase problem solving ability. 20 instructional sessions of 45 min.s for 9 weeks in special class.	Interviews conducted to obtain qualitative information on S's methods for solving word problems; percentage of problems solved correctly.	Heuristically trained S's: Better post-instruction and delayed test performance. Qualitative interviews: S's impulsively performed number operations in problems, began work quickly, read fast but missed part of the problem, drew graphic representations, looked for patterns, seldomed checked logic of steps and calculations or looked for alternative solutions, and did not separate making/carrying out plan phases well.
Neil (1968)	230 third grade students from six classes in Alabama.	Performance on arithmetic word problem solving test with/without diagrams. Two equal test forms with diagrams, given on 2 different occasions.	Two measures collected: percentages of problems without diagrams correctly solved, & percentage of problems with diagrams correctly solved.	Significant difference in the means between performance on problems with and without diagrams. Problems with diagrams were solved at a significantly higher frequency.

Table 8- Continued

Study	Subjects	Independent Variable(s)	Dependent Measures	Results
Portis (1973)	138 fourth, fifth, and sixth grade children (Bloomington, IN) divided into three ability levels based on IQ. Students at each level randomly assigned to one of 3 groups.	Relationship among grades, IQ, aids for solving of problems involving proportions.	Performance of S's on tests that contained one of 3 levels of aids (physical, pictorial, or symbolic) for solving the test problems.	Results showed a significant difference among the mean performances of S's on test accompanied by by physical or pictorial aids than performance of S's tested with problems with symbolic (words only) aids.
Threadgill-Sowder & Sowder (1982)	262 students from ten fifth grades (Calgary, Alberta, Canada.) All schools used the same mathematics series.	Effect of story format (verbal vs. drawn) on performance.	Percent correct on 2 forms of test designed to measure effect of story problem format.	Drawing scores were significantly superior to the verbal scores (t (261) = 4.64, $p < .001$). Informal interviews yielded positive preference for the drawn format (about 80%) and a perception that the drawn format simplified the word problems .
Yancey, Thompson, & Yancey (1989)	92 fourth grade students from a rural Kentucky school. 2 teachers taught 2 classes of students.	Studied effects of drawing diagrams on students' word problem solving ability. Both classes instructed in three 25 minute sessions per week for 6 weeks (diagramming and eclectic approach). Group instruction only in both classes. Same problems for both classrooms.	Percentage of correct responses on 3 equivalent verbal problem-solving tests were obtained.	Students exposed to the diagramming approach averaged a 96% improvement over their pre-test scores, the eclectic approach averaged a 40% improvement. The diagramming approach was found to be superior to the eclectic approach. Significant positive effect due to the diagramming approach.

problems in the drawn format. Four practice sets of problems were generated by the researchers in both written and drawn formats. Each set of practice materials contained eight items. All together, the researchers developed 32 items for the practice materials. The materials for both verbal and drawn conditions contained the same problems. The problems were of fifth grade level difficulty and were similar to problems found in the fifth-grade mathematics textbooks being used. A majority of the problems required that students perform only one step for solving the problem. The post-tests contained 16 items that required students to perform the four basic arithmetical calculations for problem resolution (Threadgill-Sowder & Sowder, 1982). Two alternate posttests were developed which contained the same 16 problems, in the same order, alternating between verbal and drawn formats. The forms differed in the order in which verbal and drawn problems were presented. From the post-test, the researchers were able to obtain a Drawing Score, a Verbal Score and a Total Score. Interviews were also conducted to obtain qualitative information regarding pupil preference for written verses drawn format problems (Threadgill-Sowder & Sowder, 1982).

When the group means on posttests were compared, the results indicated that the drawing scores were significantly superior to the verbal scores (t (261) = 4.64, $p < .001$) (Threadgill-Sowder & Sowder, 1982). The informal interviews conducted with the selected students and the classes, yielded positive preference for the drawn format (about 80%) and a perception that the drawn format simplified the word problems (Threadgill-Sowder & Sowder, 1982) (see Table 8).

Yancey, Thompson, and Yancey (1989) investigated the effects of instructing students to generate their own diagrams when solving word problems was examined. For their study, 2 teachers and 92 students from four fourth-grade classes from rural Kentucky were used. Each teacher taught two class periods of fourth-grade mathematics and the classes of students were randomly assigned to either the diagramming instruction section or to an eclectic instruction section. The students in the eclectic approach sections were taught to solve word problems using an approach which consisted of 10 processes that students were asked to perform when solving word problems. Students were to solve problems by (a) analyzing the problem, (b) determining the wanted or given structure, (c) noting the presence of irrelevant information or the absence of essential data, (d) translating the word problem into a number sentence, (e) determining the meaning of unfamiliar vocabulary, (f) stressing the logical order for setting up multistep word problems, (g) working on many problems, (h) examining the problem and looking it at from a smaller scale, (i) emphasizing the rereading of the problem and the rechecking of the computations performed, and (j) dramatizing of the problem situation (Yancey, Thompson, & Yancey, 1989) (see Table 8).

The students in the diagramming approach section were taught to solve problems through the use of tabular diagramming, geometric diagramming, and contingency diagramming. Tabular diagramming was a method of diagramming a word problem through the organization of the information from the problem into rows and columns. Once the data were organized, students were taught to study the relationships in the diagram, decide upon appropriate arithmetical operations that were required to solve the problem, calculate the answer, and to check the answer against the diagram (Yancey, Thompson, & Yancey, 1989).

Geometric diagramming was taught to help students solve word problems involving geometry. In that procedure, students were taught to draw the geometric figure described in the problem, label the figure with all information that was present in the problem, decide upon appropriate arithmetic operations, calculate the answer, and to check the answer with the drawing (Yancey, Thompson, & Yancey, 1989).

The third diagramming technique, contingency diagramming, was taught to students for their use when they are confronted with a word problem that had more than one unknown quantity. The steps of the contingency diagramming approach are same as the tabular diagramming approach except for one element. The element that students were taught to deal with was the calculating of answers for cells within the tables of their diagram (Yancey, Thompson, & Yancey, 1989).

The results of the study indicated that the students exposed to the diagramming approach averaged a 96% improvement over their pre-test scores, the eclectic approach averaged a 40% improvement. When the data were subjected to an analysis of covariance, the diagramming approach was found to be superior to the eclectic approach. Yancey et al. (1989) also reported that an analysis of pre- and post-test pupil attitudes toward mathematics revealed that there was a significant positive effect due to the diagramming approach.

Lee (1982) examined the use of graphical representations for solving word problems from a heuristic approach. Lee investigated the effects of the usage of specific heuristics for increasing problem solving ability among students identified as operating on Piaget's concrete stage of development. The specific heuristics involved methods suggested by Polya (see Table 8). Qualitative interviews were conducted to gather information on the subjects' methods for solving the word problems, as well as quantitative data on the performance of the subjects on mathematical word problems.

Lee (1982) found that students taught heuristic methods for problem solving performed significantly better than subjects with no heuristic instruction. Lee further observed that students would impulsively perform calculations on numbers in problems, started to work immediately, read the problem fast and missed part of the information, drew pictures, charts, or tables, looked for patterns, and would occasionally check their responses and look for alternative solutions (1982). Lee also indicated that the subjects had difficulty in separating the making of a plan and the carrying out of the plan (see Table 8).

The six studies on graphical representation of word problems provide cursory evidence that the use of diagramming or the visual/graphically representation techniques provide some assistance in helping students solve word problems. This point of view has been also supported by Shaw (1984) who suggested that students should be taught to understand that tables, charts, and graphs are used to display information and indicate relationships, and help in obtaining the correct solution to a problem. Lampert (1989) supported this idea and further stated that the use of diagrams and drawings allows students to perform needed mathematical operations, and assists in the comprehension of the mathematical process.

Examination of Effective Instructional Procedures to Promote Skill Acquisition and Generalization of New Skills

Although many researchers support the effectiveness of the direct instruction format (Darch, Carnine, & Gersten, 1984; Wilson & Sindelar, in press) for facilitating the acquisition of word problem solving skills in individuals, others support a cognitive approach for dealing with the identical goal (Davis & Hajicek, 1985; Dunlap & Dunlap, 1989; Montague & Bos, 1986).

Deshler, Alley, Warner, and Schumaker (1981) developed a technique that has incorporated many of the effective teaching procedures of direct instruction, and the cognitive behavioral modification approach for instructing students. These procedures have been effective in promoting the acquisition and generalization of learning strategies in LD adolescents. These stages of acquisition and generalization are as follows:

1. Analysis of current learning habit. The purpose of this stage is to determine the levels of expertise the student has for applying skills necessary for solving a particular task. A second component of this stage is to make the student aware of any inefficiencies that may be present in the ways the student solves or approaches a task.

2. Description of the new strategy. During this stage, the teacher describes the steps of the strategy that will be taught to the students. The teacher also provides the students with a rationale for when and where the strategy can be used.

3. Modeling of the new strategy. In this stage of the instructional sequence, the teacher models the strategy for the students. During this modeling stage, the teacher is verbally describing the steps of the strategy as he/she implements the strategy.

4. Verbal rehearsal of the strategy steps. During this stage of the instructional process, students become active participants in the learning of the strategy. The student is required to verbally rehearse each step of the strategy. This self-instructional format allows the student to internalize the strategy and be able to automatically describe the steps of the strategy.

5. Practice the strategy in controlled materials. Once students are able to automatically repeat the steps of the strategy, they are provided with applying the strategy to a series of controlled practice materials. These materials are at the student's reading level. This allows the student to practice the strategy in situations that allow for the acquisition and refinement of strategy use. During this stage corrective feedback is also provided to the students.

6. Practice the strategy in grade-level appropriate level materials. Once the student has mastered using the strategy in controlled materials, the student is then required to practice the strategy on materials that maybe used in the regular classroom. The student practices with grade-level appropriate materials until proficiency has been attained. Corrective feedback is also presented to the student in this stage of acquisition. After proficiency has been attained, students are then given a post-test and asked to make a commitment to use the strategy in their classrooms and in any situation that would be suitable for strategy use.

7. Generalization. During this stage, several techniques are implemented to assist the students in implementing the strategy. First, students are taught to cue other individuals, including the regular classroom teacher for reinforcement for using the strategy. Secondly, students are provided with diverse examples, situations, and opportunities to use the strategy. Finally, training the students to generalize is done loosely through the varying of formats and instructions so that the students will be exposed to a variety of situations that may approximate real learning situations.

The preceding instructional procedures were adapted and used in this study to train the subjects in the use of the SIGNS strategy. A detailed description of how each of these stages was accomplished and implemented for this study is found in Appendix A.

Summary

It is evident that an effective method for teaching students to solve mathematical word problems would be one that would combine the principles of effective instructional delivery, along with key practices that would facilitate the problem solving process. The effectiveness of the direct instruction procedure and its utilization of scripted and semi-scripted lessons has been demonstrated in the literature (Darch, Carnine, & Gersten, 1984; Gersten & Carnine, 1984; Gersten, Carnine, & Woodward, 1987; Wilson & Sindelar, in press). The effectiveness of the implementation of the procedures advocated by Deshler et al. (1981) for assisting students in acquiring and implementing new skills has also been shown to be effective (Ellis, Lenz, & Sabornie, 1987a; Ellis, Lenz, & Sabornie, 1987b; Ellis, Deshler, & Schumaker, 1989; Montague & Bos, 1986). The necessity of teaching students to be able to discriminate relevant information from irrelevant information has also been shown to be important (Blankenship & Lovitt, 1976; Cruickshank, 1948; Englert, Culatta, & Horn, 1987; Goodstein, Bessart, Thibodeau, Vitello, & Vlahakos, 1972; Goodstein, Cawley, Gordon, & Helfgott,1971). The effectiveness of teaching students to represent a mathematical word problem visually has also been supported in the literature (Montague & Bos, 1986; Threadgill-Sowder & Sowder, 1982; Yancey, Thompson, & Yancey, 1989). The necessity of providing students with the opportunity to generalize their newly acquired skills has also been stressed by researchers (Ellis, Lenz, & Sabornie, 1987a; Ellis, Lenz, & Sabornie, 1987b; Stokes & Baer, 1977) as being very important.

Therefore, an instructional technique that incorporates all of these elements into an instructional package was developed and examined. The SIGNS strategy incorporated all of the elements that this investigator has concluded to be effective, scripted and semi-scripted lessons following the direct instruction model, and the effective techniques of acquisition developed by Deshler et al. (1981). The strategy addressed the idea of having students reading and identifying numbers and numeric representations of objects that may be vital for the solving of a word problem. A majority of researchers have proposed that this strategy is necessary (see Table 9). The SIGNS strategy required students to visually represent the word problem which is consistent with methods posited by Lee (1982), Nuzum (1987), Yancey, Thompson, and Yancey (1989) and others (see Table 9).

The SIGNS strategy included a generalization phase to promote the strategy utilization by students in a variety of situations. The generalization phase of the SIGNS strategy was unique in that it presented the students with instruction on how to form their own word problems. While the procedure were similar to the procedures suggested by Deshler et al. (1981), the initial phases of generalization did not follow the "Train Loosely" concept proposed by Stokes and Baer (1977), Deshler et al. (1981), and Ellis, Lenz and Sabornie (1987a,1987b). The instructions for assisting students to form their own problems were in a direct instruction format and presented opportunities for the students to practice applying the strategy.

The SIGNS strategy incorporated the use of a mnemonic device in assisting students to recall the stages of the problem solving process. The inclusion of a mnemonic device was unique to this problem solving method. An examination of Table 9 revealed that currently, there are no other methods for solving word problems that utilize a mnemonic device.

Table 9: Comparison of Methods with Components of SIGNS strategy

	Direct Instruction	Cognitive	Mnemonics	Read	Underline Numbers	Identify keywords	Draw Picture	Draw Tables	Draw Charts	Reread problem	Observe drawing	Write equation	Compute answer	Check answer	Complete answer	Generalization	Make Own problems
Talton (1988)		√		√								√	√	√			
Smith & Alley (1981)		√		√		√				√		√	√	√	√		
Yancey, et al. (1989)							√	√	√			√	√	√			
Lee (1982)		√		√		√	√	√	√				√	√		√	
Nuzum (1987)	√	√		√		√	√	√	√	√	√		√	√	√		
Huinker (1989)		√				√	√	√	√			√	√			√	√
Ross, et al. (1988)				√								√	√			√	√
Charles & Lester (1984)		√		√	√	√	√	√	√			√	√	√	√		
Montague & Bos (1986)	√	√		√	√	√	√	√	√			√	√	√	√		
Darch, et al. (1984)	√			√		√						√			√		
Jones, et al. (1985)	√			√								√	√	√			√

CHAPTER III

METHODS AND PROCEDURES

Introduction

The research method outlined in this chapter consists of applied behavior analysis procedures that were used to investigate the effectiveness of an intervention for teaching students with mild disabilities to solve mathematical word problems. The primary questions investigated were:

1. Do students with mild disabilities acquire a mathematical problem solving strategy which includes direct and mnemonic instruction?

2. Do students with mild disabilities retain a mathematical problem solving strategy which includes direct and mnemonic instruction?

3. Do students with mild disabilities generalize a mathematical problem solving strategy which includes direct and mnemonic instruction to the solving of multistep mathematical word problems?

The methodology of this investigation is discussed according to setting, subject description and selection, and a description of the treatment procedure. Instructional procedures, reliability and validity procedures, experimental design, and data analysis are also presented.

Setting

The research was conducted at three schools in Alachua County, Florida. Schools and classrooms were selected for inclusion in the study because three teachers expressed a willingness to participate in the study. Teachers selected to participate in the study were employed by the school district to serve as teachers of students of varying exceptionalities (VE) or emotional handicaps (EH) and assigned to teach mathematics. Experimental sessions consisted of individual to small group instruction (approximately 1 to 3 students) per class period. The classrooms were of standard size and contained both individual student desks and large tables for group activities. All classrooms were located in a permanent facility. No classrooms were in relocatable classrooms.

The schools involved were A. Quinn Jones Center School, Hawthorne Junior-Senior High School, and Westwood Middle School. A description of each school setting is presented.

A. Quinn Jones Center School is an educational facility used by Alachua County for providing instructional services to students with emotional and behavior disabilities. A. Quinn Jones Center School has a current enrollment of 133 students, 18 females and 115 males. Sixty-three percent of the students at A. Quinn Jones Center School are of African-American descent. Students attending the school are transported from various locations throughout the county and have been placed in the program at A. Quinn Jones Center School in accordance to suggested remedies outlined in each student's Individualized Education Plan (IEP). A. Quinn Jones Center School is centrally located within the city of Gainesville and provides instruction for students in Grades 1 through 12.

Hawthorne Junior-Senior High School is a combination junior high school and senior high school designed to serve the educational needs of students from the eastern section of Alachua County. Students attending Hawthorne Junior-Senior High School come from various rural communities surrounding the city of Hawthorne. Current enrollment of Hawthorne Junior-Senior High School is 554 students, 261 females and 293 males. The combined student body at Hawthorne Junior-Senior High School is composed of approximately 30% African-American students. Hawthorne Junior-Senior High School provides educational services for students in Grades 6 through 12.

Westwood Middle School is a large, urban middle school providing educational services to approximately 882 students, 426 females and 456 males. The current student body population is approximately 31 percent African-American and 69 percent other racial and ethnic groups. A majority of the African-American students are transported to Westwood Middle School from various sections of the city of Gainesville and the county of Alachua. Westwood Middle School provides instructional services for students in Grades 6 through 8.

Subject Description and Selection

Subjects consisted of seventh- and eighth-grade students educated in one special school and two secondary schools. The ten subjects selected were identified as students with mild disabilities and were served in self-contained EH classrooms or in non-categorical resource varying exceptionalities (VE) classrooms. The teachers of the three classrooms involved in the study expressed an interest in participating.

Students with mild disabilities included students identified as being learning disabled, or emotionally handicapped. Students selected for participation met the criteria for being identified as learning disabled, or emotionally handicapped, and met the criteria and guidelines set forth by the state of Florida.

To obtain the ten subjects for this study, two VE teachers and one EH teacher were asked to make a list of their students who they believed met the subject selection criteria. Parental consent letters for participation in the study were sent to students on the list.. Once letters were signed and returned, students records were examined to ascertain whether the students met the criteria for subject selection. Information regarding the students' IQ and achievement levels were obtained from individual school folders. Subjects 1, 2, and 3 were taught by 1 teacher. Subjects 4, 5 and 6 were taught by another teacher, and Subjects 7, 8, 9, and 10 were taught by a third teacher.

Teachers selected students who exhibited difficulties in solving mathematical word problems and were able to read at or above the fourth grade reading level. Students selected were screened for inclusion in the study by assessing their abilities to perform and demonstrate competency in the basic computational skills areas: addition, subtraction, and multiplication, on three 1-minute precision teaching probes developed by the Orange County Public Schools Precision Teaching Project (sheets A-5, S-5, and M-9M). A pretest was also administered to sample word problem solving abilities.

Demographic information on subjects was collected, and included special education category, placement, age, grade level, IQ, sex, race, and standardized test scores in respective achievement areas. Information was obtained from student files.

Approval for the youth to be tested, trained, and observed was obtained from the University of Florida Institutional Review Board (see Appendix B), the School Board of Alachua County (see Appendix C), and the student's parents (see Appendix D). Student consent for participation was also obtained and a student assent script was administered (see Appendix E).

Subject 1

Subject 1 (S1) was a eighth-grade African-American female, age 13 years 10 months attending Westwood Middle School. Subject 1 was receiving educational services from three varying exceptionalities (VE) teachers during a normal school day. Subject 1 was placed in VE classes for reading/language arts, study skills, and mathematics. Subject 1 was identified as having specific learning disabilities (SLD) and had received services from exceptional student education (ESE) teachers for five years. Subject 1 did not have any physical or sensory impairments, or extreme behavior problems.

In 1988, Subject 1 was administered the Weschler Intelligence Scale for Children-Revised (WISC-R) and attained a Full Scale Intelligence Quotient (FIQ) score of 92 (see Table 10). At the start of the 1990-91 school year, Subject 1 was administered the Wide Range Achievement Test and attained a 6.5 grade level score for mathematics and 5.0 grade level score for reading (see Table 11). On the 1-minute precision teaching screening measures, Subject 1 correctly computed 35 items with 0 mistakes on the addition measure, 18 items with 0 mistakes on the subtraction measure, and 45 items with 0 mistakes on the multiplication measure.

The VE teacher for mathematics reported that although S1 was able to perform basic mathematical computational problems, she had great difficulty solving mathematical word problems. The teacher also reported that S1 exhibited an unstable pattern for learning new material. The teacher stated that S1 would make progress learning new material daily for a period of several weeks and then would experience difficulties in completing the same material the following weeks. The teacher indicated that a similar pattern could possibly be exhibited during the time period in which the subject would be

Table 10 - Test Scores for Subjects' Level of Intellectual Functioning

Subject	Test	Date	Scale	Score
1	WISC-R	1988	Full Scale IQ	92
2	K-ABC	1989	Mental Processing Composite	90
3	K-ABC	1989	Mental Processing Composite	95
4	WISC-R	1989	Full Scale IQ	93
5	WISC-R	1989	Full Scale IQ	91
6	WISC-R	1989	Full Scale IQ	97
7	K-ABC	1990	Mental Processing Composite	87
8	K-ABC	1990	Mental Processing Composite	94
9	K-ABC	1989	Mental Processing Composite	95
10	K-ABC	1990	Mental Processing Composite	95

Note: WISC-R: Weschler Intelligence Scale for Children-Revised
K-ABC: Kaufman-Assessment Battery for Children

Table 11 - Subjects' Achievement and Prescreening Test Scores

Subject	Grade Level	Mathematics	Reading	+	-	x
1	8	WRAT: 6.5	WRAT: 5.0	35/0	18/0	45/0
2	7	WRAT: 6.5	WRAT: 4.6	76/6	35/1	70/1
3	7	WRAT: 6.5	WRAT: 4.6	49/0	25/0	39/0
4	8	CAT: 5.3	CAT: 3.9	50/0	17/3	65/6
5	8	CAT: 5.5	CAT: 5.4	35/0	18/0	42/0
6	8	CAT: 6.6	CAT: 5.4	35/0	18/0	29/0
7	7	K-TEA: 4.6	K-TEA: 4.0	43/0	19/0	44/6
8	7	K-TEA: 4.2	K-TEA: 3.5	12/0	13/0	27/0
9	8	K-TEA: 5.8	K-TEA: 4.2	45/0	20/0	37/0
10	7	K-TEA: 6.2	K-TEA: 5.5	64/1	34/1	55/0

Note:

WRAT:	Wide Range Achievement Test
CAT:	California Achievement Test
K-TEA:	Kaufman Test of Educational Achievement
+ :	Addition Prescreening Measure
- :	Subtraction Prescreening Measure
x :	Multiplication Prescreening Measure
#/# :	Correct/Errors

taught the mathematical word problem solving strategy.

Subject 2

Subject 2 (S2) was a seventh-grade African-American male, age 13 years 8 months attending Westwood Middle School. Subject 2 was also receiving educational services from three varying exceptionalities (VE) teachers during a normal school day. Subject 2 was placed in VE classes for reading/language arts, study skills, and mathematics. Subject 2 was identified as having specific learning disabilities (SLD) and had received services from exceptional student education (ESE) teachers for four years. Subject 2 did not have any physical or sensory impairments, or extreme behavior problems.

In 1989, Subject 2 was administered the Kaufman-Assesment Battery for Children (K-ABC) and attained a Mental Processing Composite score of 90 (see Table 10). At the start of the 1990-91 school year, Subject 2 was administered the Wide Range Achievement Test and attained a 6.5 grade level score for mathematics and 4.6 grade level score for reading (see Table 11). On the 1-minute precision teaching screening measures, Subject 2 correctly computed 76 items with 6 mistakes on the addition measure, 36 items with 1 mistake on the subtraction measure, and 70 items with 1 mistake on the multiplication measure.

The VE teacher for mathematics reported that although S2 was able to perform basic mathematical computational problems, he exhibited difficulty solving mathematical word problems. The teacher also reported that S2 learns new material slowly, and might have problems learning the mathematical word problem solving strategy.

Subject 3

Subject 3 (S3) was a seventh-grade African-American male, age 13 years 7 months also attending Westwood Middle School. Subject 3 was receiving educational services from three varying exceptionalities (VE) teachers during a normal school day. Subject 3 was placed in VE classes for reading/language arts, study skills, and mathematics. Subject 3 was identified as having specific learning disabilities (SLD) and had received services from exceptional student education (ESE) teachers for four years. Subject 3 did not have any physical or sensory impairments, or extreme behavior problems.

In 1989, Subject 3 was administered the Kaufman-Assessment Battery for Children (K-ABC) and attained a Mental Processing Composite score of 95 (see Table 10). At the start of the 1990-91 school year, Subject 3 was administered the Wide Range Achievement Test and attained a 6.5 grade level score for mathematics and 4.6 grade level score for reading (see Table 11). On the 1-minute precision teaching screening measures, Subject 3 correctly computed 49 items with 0 mistakes on the addition measure, 25 items with 0 mistakes on the subtraction measure, and 39 items with 0 mistakes on the multiplication measure.

The VE teacher for mathematics reported that although S3 was able to perform basic mathematical computational problems, he experienced difficulties solving mathematical word problems. The teacher also noted that S3 would probably learn and implement the strategy quicker than the other students in her class. The teacher reported that S3 was a hard worker and was not frequently absent. The teacher also indicated that S3 was occasionally disruptive.

Subject 4

Subject 4 (S4) was a eighth-grade African-American male, age 14 years 9 months attending Hawthorne Junior-Senior High School. Subject 4 was receiving educational services from two varying exceptionalities (VE) teachers during a normal school day. Subject 4 was placed in VE classes for functional language, study skills, job skills, and mathematics. Subject 4 was identified as having specific learning disabilities (SLD) and had received services from exceptional student education (ESE) teachers for seven years. Subject 4 did not have any physical or sensory impairments, or extreme behavior problems.

In 1989, Subject 4 was administered the Weschler Intelligence Scale for Children-Revised (WISC-R) and attained a Full Scale Intelligence Quotient (FIQ) score of 93 (see Table 10). Reading and mathematics achievement scores from the California Achievement Test obtained from his student records were 3.9 grade level and 5.3 grade level respectively (see Table 11). On the 1-minute precision teaching screening measures, Subject 4 correctly computed 50 items with 0 mistakes on the addition measure, 17 items with 3 mistakes on the subtraction measure, and 65 items with 6 mistakes on the multiplication measure.

The VE teacher for mathematics reported that although S4 was able to perform basic mathematical computational problems, he experienced problems solving mathematical word problems. The teacher noted that S4 was a hard worker and was not frequently absent. The teacher stated that S4 was not a behavior problem.

Subject 5

Subject 5 (S5) was an eighth-grade Caucasian male, age 13 years 9 months attending Hawthorne Junior-Senior High School. Subject 5 was receiving educational services from two varying exceptionalities (VE) teachers during a normal school day. Subject 5 was placed in VE classes for study skills, job skills, and mathematics. Subject 5 was identified as having specific learning disabilities (SLD) and had received services from exceptional student education (ESE) teachers for five years. Subject 5 did not have any physical or sensory impairments, or extreme behavior problems.

In 1989, Subject 5 was administered the Weschler Intelligence Scale for Children-Revised (WISC-R) and attained a Full Scale Intelligence Quotient (FIQ) score of 91 (see Table 10). Reading and mathematics achievement scores from the California Achievement Test obtained from his student records were 5.4 grade level and 5.5

grade level respectively (see Table 11). On the 1-minute precision teaching screening measures, Subject 5 correctly computed 35 items with 0 mistakes on the addition measure, 18 items with 0 mistakes on the subtraction measure, and 42 items with 0 mistakes on the multiplication measure.

The classroom teacher reported that although S5 was able to perform basic mathematical computational problems, he had problems with the solving of mathematical word problems. The teacher also noted that S5 was a hard worker and was not frequently absent. The teacher reported that S5 was not a behavior problem.

Subject 6

Subject 6 (S6) was an eighth-grade Caucasian male, age 14 years 1 month attending Hawthorne Junior-Senior High School. Subject 6 was receiving educational services from two varying exceptionalities (VE) teachers during a normal school day. Subject 6 was placed in VE classes for functional language, study skills, job skills, and mathematics. Subject 6 was identified as having specific learning disabilities (SLD) and had received services from exceptional student education (ESE) teachers for five years. Subject 6 did not have any physical or sensory impairments, or extreme behavior problems.

In 1989, Subject 6 was administered the Weschler Intelligence Scale for Children-Revised (WISC-R) and attained a Full Scale Intelligence Quotient (FIQ) score of 97 (see Table 10). Reading and mathematics achievement scores from the California Achievement

Test obtained from his student records were 5.4 grade level and 6.6 grade level respectively (see Table 11). On the 1-minute precision teaching screening measures, Subject 6 correctly computed 35 items with 0 mistakes on the addition measure, 18 items with 0 mistakes on the subtraction measure, and 29 items with 0 mistakes on the multiplication measure.

The mathematics teacher for exceptional student education reported that although S6 was able to perform basic mathematical computational problems, he had difficulties solving mathematical word problems. The teacher reported that S6 was a hard worker, but completed work slowly. The teacher also reported that S4 was not a behavior problem and was not frequently absent.

Subject 7

Subject 7 (S7) was a seventh-grade African-American male, age 13 years 6 months attending A.Quinn Jones Center School. Subject 7 was receiving educational services from numerous teachers of the emotionally and behaviorally disabled during of a normal school day. Subject 7 was identified as having emotional and behavioral disabilities and had received services from exceptional student education (ESE) teachers for four years. Subject 7 did not have any physical or sensory impairments, but exhibited severe disruptive, non-compliant, and aggressive behaviors.

In 1990, Subject 7 was administered the Kaufman-Assessment Battery for Children (K-ABC) and attained a Mental Processing

Composite score of 87 (see Table 10). Reading and mathematics composite scores from the Kaufman Test of Educational Achievement were 4.0 grade level and 4.6 grade level respectively (see Table 11). On the 1-minute precision teaching screening measures, Subject 7 correctly computed 43 items with 0 mistakes on the addition measure, 19 items with 0 mistakes on the subtraction measure, and 44 items with 0 mistakes on the multiplication measure.

The mathematics teacher reported that although S7 was able to perform basic mathematical computational problems, he experienced difficulties with the solving of mathematical word problems. The teacher noted that S7 would probably learn and implement the strategy slowly. The teacher reported that S7 was usually a hard worker but was frequently absent.

Subject 8

Subject 8 (S8) was a seventh-grade African-American male, age 13 years 9 months attending A.Quinn Jones Center School. Subject 8 was receiving educational services from numerous teachers of the emotionally and behaviorally disabled during a normal school day. Subject 8 was identified as having emotional and behavioral disabilities and had received services from exceptional student education (ESE) teachers for four years. Subject 8 did not have any physical or sensory impairments, but exhibited severe disruptive, non-compliant, and aggressive behaviors.

In 1990, Subject 8 was administered the Kaufman-Assessment Battery for Children (K-ABC) and attained a Mental Processing Composite score of 94 (see Table 10). Reading and mathematics composite scores from the Kaufman Test of Educational Achievement were 3.5 grade level and 4.2 grade level respectively (see Table 11). On the 1-minute precision teaching screening measures, Subject 8 correctly computed 12 items with 0 mistakes on the addition measure, 13 items with 0 mistakes on the subtraction measure, and 27 items with 0 mistakes on the multiplication measure.

The mathematics teacher reported that although S8 was able to perform basic mathematical computational problems, he experienced difficulties solving mathematical word problems. The teacher also reported that S8 would probably learn and implement the strategy slowly. The teacher also noted that S8 was usually slow to finish his work, and would exhibit abusive language and disruptive behaviors when frustrated.

Subject 9

Subject 9 (S9) was an eighth-grade African-American male, age 14 years 5 months attending A.Quinn Jones Center School. Subject 9 was receiving educational services from numerous teachers of the emotionally and behaviorally disabled during a normal school day. Subject 9 was identified as having emotional and behavioral disabilities and had received services from exceptional student education (ESE) teachers for six years. Subject 9 did not have any physical or sensory impairments, but exhibited severe disruptive, non-compliant, and aggressive behaviors.

In 1989, Subject 9 was administered the Kaufman-Assessment Battery for Children (K-ABC) and attained a Mental Processing Composite score of 95 (see Table 10). Reading and mathematics composite scores from the Kaufman Test of Educational Achievement were 4.2 grade level and 5.8 grade level respectively (see Table 11). On the 1-minute precision teaching screening measures, Subject 9 correctly computed 45 items with 0 mistakes on the addition measure, 20 items with 0 mistakes on the subtraction measure, and 37 items with 0 mistakes on the multiplication measure.

The mathematics teacher reported that although S9 was able to perform basic mathematical computational problems, the solving of mathematical word problems were difficult for him. The teacher noted that S9 was frequently absent and did not like attending school.

Subject 10

Subject 10 (S10) was a seventh-grade Caucasian male, age 13 years 8 months attending A.Quinn Jones Center School. Subject 10 was receiving educational services from numerous teachers of the emotionally and behaviorally disabled during a normal school day. Subject 10 was identified as having emotional and behavioral disabilities and had received services from exceptional student education (ESE) teachers for three years. Subject 10 did not have any physical or sensory impairments, but exhibited severe disruptive, non-compliant, and aggressive behaviors.

In 1990, Subject 10 was administered the Kaufman-Assessment Battery for Children (K-ABC) and attained a Mental Processing Composite score of 95 (see Table 10). Reading and mathematics composite scores from the Kaufman Test of Educational Achievement were 5.5 grade level and 6.2 grade level respectively (see Table 11). On the 1-minute precision teaching screening measures, Subject 10 correctly computed 64 items with 1 mistake on the addition measure, 34 items with 1 mistake on the subtraction measure, and 55 items with 0 mistakes on the multiplication measure.

The classroom teacher reported that the solving of mathematical word problems was a difficult task for S10. The teacher noted that S10 would probably learn and implement the strategy quickly. The teacher reported that S10 was usually a hard worker. The teacher indicated that when S10 made up his mind not to do something, he would not do it even when presented with tangible reinforcers.

Description of Word Problem-Solving Strategy

The independent variable used in this study was the mathematical word problem-solving strategy SIGNS (see Table 12). The SIGNS strategy incorporates principles found to be effective in assisting learners to solve mathematical word problems. The mnemonic SIGNS was developed to increase the likelihood that subjects would

Table 12: The SIGNS Strategy

Name of Component: S - **Survey**

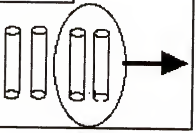
Behavioral Sequence	Measurement	Example
1. Read the question	1. No measure	
2. Underline the numbers and/or number words.	2. Probes will be examined to see if the subject has underlined the numbers and/or number words.	"Mrs. Harris has four pens. She gave 2 pens to Mike. How many pens does she have left?"

Name of Component: I - **Identify**

Behavioral Sequence	Measurement	Example
3. Draw 2 lines under the key words and details of the question.	3. Probes will be examined to see question if the subject has underlined the key words and details with 2 lines.	"Mrs. Harris has four pens. She gave 2 pens to Mike. How many pens does she have left?"

Table 12---continued

Name of Component: G - **Graphically**

<table>
<tr><th>Behavioral Sequence</th><th>Measurement</th><th>Example</th></tr>
<tr><td>4. Draw or diagram the problem.</td><td>4. Probes will be examined to see if the subject has drawn or diagrammed the problem.</td><td>Student has drawn a picture representing the action occurring in the problem: "Mrs. Harris has four pens. She gave 2 pens to Mike. How many pens does she have left?"</td></tr>
<tr><td colspan="3"></td></tr>
</table>

Name of Component: N - **Note operation**

Behavioral Sequence	Measurement	Example
5. Decide what math operation is needed to solve the problem.	5. No measure	
6. Write down the operation that will be used.	6. Probes will be examined to see if the subject has written down the operational symbols or mathematical equations needed to.solve the problem.	Student has written "4 - 2 = ___ pens"

Table 12---continued

Name of Component: S - **Solve and check**

Behavioral Sequence	Measurement	Example
7. Compute the answer and write it down.	7. Probes will be examined to see if the subject has computed the problem and has written down the answer.	Student has written "4 - 2 = 2."
8. Write details with the answer.	8. Probes will be examined to see if details are written with answer.	Student has written "4 - 2 = 2 pens."
9. Check the answer.	9. Probes will be examined to see if the subject has performed self-checking of the answer.	Student has written a √ next to problem indicating that problem was checked
10. Circle your complete answer.	10. Probes will be examined to see if the subject has circled the complete answer.	Student has circled 2 pens. 4 - 2 = 2pens

remember the strategy when presented with the task of solving mathematical word problems.

The following description includes the word/phrase with which each letter of the acronym is to be associated. The description also provides a list of the subject behaviors that need to be exhibited within each component, and the specific parameters for the measurement of each specific behavior.

Instructional Procedures

The mathematical word problem-solving strategy SIGNS was taught to subjects through the use of instructional procedures designed for developing and promoting skill acquisition and generalization in LD adolescents (Ellis, Deshler, Lenz, Schumaker, & Clark, 1991). For this study, modifications of Ellis et al (1991) acquisition and generalization stages were used. The following section lists and describes each of the instructional procedures used in this study (see Appendix A for a more detailed description).

Stage 1: Pretest and Make Commitments

Purpose: To provide a written description of each subject's use of word problem-solving skills that are contained within the components of the SIGNS strategy.

Stage 2: Describe the Strategy

Purpose: To describe the steps of the SIGNS strategy and to provide the subjects with a rationale for strategy use.

Stage 3: Model the Strategy

Purpose: To model the SIGNS strategy, in its entirety, to students through the concurrent demonstration and verbal description of the procedures.

Stage 4: Verbal Practice

Purpose: To be certain that the subjects can verbally state the component steps of the SIGNS strategy automatically through rehearsing the steps of the strategy and verbally explaining the function of each step..

Stage 5: Controlled Practice and Feedback

Purpose: To provide students practice in the use of the SIGNS strategy with materials specifically developed for the strategy, and to provide students with elaborated feedback pertaining to the acquisition and accurate demonstration of the SIGNS strategy. Elaborated feedback required the teacher to conduct an error analysis of the students' work and to model skills the student should apply for correct problem resolution (Kline, 1990).

Stage 6: Advanced Practice and Feedback

Purpose: To provide students practice in the use of the SIGNS strategy with mathematical word problems taken from Heath Mathematics: Levels 5 and 6 (Rucker, Dilley, & Lowery, 1988a,b) basal mathematics series. Word problems taken from the mathematics basal series required students to perform addition, subtraction, and multiplication operations. The Heath basal mathematics series is used in schools in which the study was conducted.

Stage 7: Post test and maintenance

Purpose: To provide a written description of each subject's use of word problem-solving skills that are contained within the components of the SIGNS strategy after training in the strategy, and to monitor students' continued use of the strategy.

Stage 8: Assessment of and Promotion of Generalization

Purpose: To promote generalization of the SIGNS strategy to the solving of mathematical word problems.

Instruments

In this study, three types of research instruments were used (see Appendix F). Two of the instruments were experimenter-made devices. The third set of research instruments were precision teaching forms assessing basic addition, subtraction, and multiplication skills. The precision teaching were developed by a school district in the state of Florida. An explanation of each of the instruments is provided as well as reliability and validity procedures for these instruments. The procedures implemented to ensure content validity and the equivalency of probes used to measure acquisition and generalization of the SIGNS strategy are provided.

Screening Device

A screening device was used to determine computational abilities of prospective subjects. The screening device consisted of items covering basic addition (Sums 0 - 18), subtraction (Minuends 0-18), and multiplication facts (0-9 multiplication facts). The screening device consisted of three precision teaching see-write sheets developed by the Orange County Public Schools Precision Teaching Project (sheets A-5, S-5, and M-9M). Problems were presented to the subjects so as to allow prospective subjects with enough situations to demonstrate competency in addition, subtraction, and multiplication (Wallace & Larsen, 1978) so that basic skills competency was not manifested as a confounding variable.

The screening device is an alternative for examining an individual's ability to demonstrate specific mathematical calculations. Informal mathematical tests and screening devices allow researchers to learn more about a subject's knowledge of basic mathematical calculations (McLoughlin, & Lewis, 1990) and have been used in experimental and clinical settings (Peterson, 1988; Smith, 1973).

Content Validity of Screening Test

The six types of mathematical computation problems contained skills that Evans, Evans, and Mercer (1986) indicated are covered in the scope and sequence of mathematics programs from Kindergarten to fourth grade. Evans and her associates (1986) noted that the addition and subtraction of numbers without regrouping is present in the scope-and-sequence of a first grade mathematics program. Evans et al. (1986) further stated that addition and subtraction with regrouping occurs during second grade mathematics instruction, and multiplication with 1 digit multipliers are present during third grade mathematics instruction. Multiplication involving 2 digit multipliers was usually introduced during the fourth grade (Evans, Evans, & Mercer, 1986).

A scope and sequence for the addition, subtraction, and multiplication of whole numbers for Kindergarten through sixth grade (Evans, Evans, & Mercer, 1986) was provided validators. The scope and sequence was provided so that validators were able to judge whether a specific item corresponds to skills that are present in the Kindergarten through sixth grade basal mathematics curriculums.

Experimenter-Made Probes

The word problems in the probes consisted of mathematical skills and operations that are present in current basal mathematics textbooks (Evans, Evans & Mercer,1986). Evans and her associates indicate that third graders are required to be able to solve word problems containing addition, subtraction, multiplication and division operations of whole numbers. They also state that basal mathematical texts require fourth graders to be able to add and subtract fractions and decimals, and compute averages. Moreover, Evans et al. (1986) note that fifth graders are required to be able to add and subtraction fractions and mixed numbers, multiply and divide fractions and decimals, and calculate discounts, sales taxes and profits. Evans et al. (1986) indicate that students, third grade and higher, are required to solve a variety of word problems. In this study the word problems that students were administered and taught to solve was restricted to the addition, subtraction, and multiplication of whole numbers.

The readability grade level of the story problems was also examined. The problems were analyzed through the use of Fry's readability analysis. Word problems were written on the 3rd - 4th grade reading level. A computer software program was used in determining readability levels of the the word problems.

Word problems for the treatment worksheets and probes were developed using words taken from The Instant Words Criterion Test: A word list and a diagnostic test (Fry, 1980) and from The NEW Reading Teacher's Book of Lists (Fry, Fountoukidis, & Polk, 1985). The word list from The Instant Words Criterion Test: A word list and a diagnostic test consists of words that are most common in the English language (Fry, 1980) and account for 65% of all written material (Fry, 1980). The word lists from The NEW Reading Teacher's Book of Lists consist of mathematical terms and words that are commonly found and used in elementary and upper elementary mathematics textbooks (Fry, Fountoukidis, and Polk, 1985). The derived words served as the basic vocabulary terms used in all of the word problems.

Two types of probes were developed, mixed and multistep probes. The first type of experimenter-made probes were constructed to assess students ability to solve mathematical word problems covering addition, subtraction, and multiplication operations. These probes were called baseline, acquisition, and maintenance (BAM) probes. Eighteen item probes were developed and contained six addition, six subtraction, and six multiplication word problems. The items on the BAM probes contained extraneous information that were not essential for correct resolution of the word problems. Six different forms of BAM probes were developed.

The BAM probes were used to obtain information regarding the acquisition of the SIGNS strategy by students. The information that was obtained from the probes included: (a) the number of appropriate marks made by the student that corresponded to the SIGNS strategy, (b) the number of inappropriate marks made by the student that corresponded to the SIGNS strategy, (c) the number of problems correctly solved by the student, and (d) the number of problems incorrectly solved by the student.

The second type of experimenter-made probes were constructed to assess the subjects' ability to generalize the SIGNS strategy to multistep word problems. These multistep probes were called generalization (G) probes. These G probes contained 18 problems. Six of the problems required the subjects to solve problems containing addition and subtraction operations, six of the problems required subjects to solve problems containing addition and multiplication operations, and six problems required subjects to solve problems involving subtraction and multiplication operations. All of the problems included extraneous information.

The G probes were designed to assess the students' ability to solve multistep word problems. The G probes were also designed to gauge whether the students needed to be taught generalization procedures for solving word problems.

Content Validity and Equivalency of Experimenter-Made Probes

Validation of the baseline, acquisition, and maintenance, and generalization probes was also conducted through content validation procedures. Three professionals in special education were asked to examine the probes and answer the following questions:

1. Do the probes contain word problems requiring subjects to either add, subtract or multiply in order to arrive at a correct solution?

2. Are the probes equivalent in the number, types of operations, and behaviors they assess?

3. Are the formats for the probes equivalent?

4. Are the probes written between the third and fourth grade reading level?

The individuals who assessed content validity and equivalency of the mixed and multistep probes were provided a specification blueprint for the probes containing instructions with regard to number of items per operation per probe. Word lists from The Instant Words Criterion Test: A word list and a diagnostic test (Fry,

1980) and The NEW Reading Teacher's Book of Lists (Fry, Fountoukidis, and Polk, 1985) were also provided to allow validators to see that the probes contained vocabulary between the third- and fourth-grade reading level. Procedures for scoring the probes were also provided.

A skill hierarchy for the addition, subtraction, and multiplication of whole numbers for sixth-, seventh-, and eighth-graders was provided to the validators. The skill hierarchy was obtained by compiling information on the addition, subtraction, and multiplication of whole numbers from five basal mathematics curricula. The skill hierarchy was provided so that validators were able to judge whether a specific item measures a skill that was covered in sixth-, seventh-, and eighth-grade basal mathematics curriculums.

All three validators agreed that a majority of the items (95% of the items) on the probes followed the specification guidelines established for problem construction. The items that were questioned by the validators were removed and new items were constructed and added to the probes.

A brief description of each instrument that was used in this study is provided in Table 13. Table 13 also provides the types of information that was collected and how the information was used.

Table 13: Instruments

Name of Instrument	**Description**	**Type of Information**
Pretest Screening Test	3 See-Write Precision Teaching Sheets developed by Orance County Public School Precision Teaching Project covering addition (Sums 0-18), subtraction (Minuends 0-18), and multiplication (0X -9X) facts. Administered once.	Determine if subjects are able to use basic addition, subtraction, and multiplication skills.
Experimenter-Made BAM Probes	18 -item probe sheets. 6 each of addition, subtraction, and multiplication word problems. 6 different forms with different word problems and presented in different order. Administered daily during baseline, and acquisition condition, and periodically during maintenance. 5 minute time limit.	Data collected with regard to: **Number** of appropriate and inapproriate SIGNS marks/movements written per 5 minute time period. **Number** of problems correctly and incorrectly solved. Data collected and charted daily and charted on 3 separate charts per subject.during baseline, acquisition and maintenance phases.

Table 13 - Continued

Name of Instrument	**Description**	**Type of Information**
Experimenter-Made Generalization (G) Probes	18 -item probe sheets. 6 each of addition and subtraction, addition and multiplication, subtraction and multiplication multi-step word problems. 6 different forms with different word problems and presented in different order. Administered daily during during maintenance to assess generalization. 5 minute time limit.	Data collected with regard to: **Number** of appropriate and inappropriate SIGNS marks written per 5 minute time period. **Number** of problems solved correctly and incorrectly. Data collected and charted daily and charted on 3 separate charts per subject.during maintenance phase.

Reliability of Procedures

Several procedures were used before and during the experiment to establish reliability of measurement and instructional procedures. Interscorer agreement, and procedural reliability checks were implemented to obtain reliability information.

Interscorer Agreement

During the research study, three colleagues of the experimenter were given copies of 27 acquisition probes randomly selected by the researcher and copies of scoring procedures (see Appendix G). The acquisition probes had previously been scored by another individual. This procedure was implemented to assess interscorer agreement percentages. Each of the scorers were provided with a training session for learning how to score the probes. Each individual scored 155 word problems across 10 areas. The 10 areas were appropriate and inappropriate marks for each of the 5 steps of the SIGNS Word Problem Solving Strategy. Interscorer agreement percentages were obtained by dividing the number of possible agreements for the probes into the actual number agreements recorded, and by dividing the number of nonagreements recorded for the probes by the total number of possible agreements. The results of the interscorer reliability checks are reported in Chapter IV.

Procedural Reliability

Procedural reliability was established through the use of three independent observers. The observers randomly observed teachers during five instructional sessions to determine whether instructional procedures were consistent and were maintained between the sets of subjects, and whether probes were administered to and completed by subjects without assistance.

The observers recorded teacher behaviors across the areas of (a) following the script, (b) following the sequence of the instructional procedures, (c) fluent pacing of the instruction, and (d) use of materials appropriately. An interval recording system was implemented to measure the teachers' behaviors. While the teachers were delivering instruction to the subjects, the observers listened to a cassette tape that designated 30-second intervals with a beep. Each time the beep was heard, the observers recorded either appropriate or inappropriate behaviors on the provided form (see Appendix H). The tape allowed for 20 intervals to be observed. Interobserver agreement was determined as is reported in Chapter IV.

Observers were trained concurrently with the teachers in the administration of the probes, and in the implementation of the instructional procedures. The description of the training session is discussed.

Training of Personnel

Prior to the beginning of the study, personnel were trained in implementing the procedures, observing the procedures for procedural reliability, and for interscorer reliability. The training of teachers and observers were done concurrently. The training of the individuals involved in interscorer reliability were held separate from the other training sessions.

Training of teachers

The three teachers involved in the study attended several training workshops in which administration and implementation of the procedures, and information on effective teaching behaviors were presented. The teachers were introduced to the word problem solving strategy, the sequence of instruction, and the procedures for administering the probes. The researcher served as the trainer for the workshops, and demonstrated and modeled the procedures that the teachers were to use when implementing the strategy.

Training of observers

Two additional individuals attended the training workshops. These two individuals, along with the researcher, were to serve as observers for procedural reliability checks on the delivery of instruction by the participating teachers. The observers were presented with the same identical information as the teachers. The observers were also provided instruction in using the tape recorded cassette with the audible beeps, and in recording the teacher's behaviors on the interval recording form.

Training of scorers for reliability checks

Three individuals served independent scorers for the probes that were being sampled for interscorer reliability procedures. Scorers were provided with two 1-hour training sessions on how to score the probes. The researcher met individually with each of the scorers and provided training. The researcher also was available for any questions that the scorers had about the scoring procedures.

Materials

Experimenter-made controlled practice worksheets were given to students after they were able to verbally state the steps of the SIGNS strategy with 100% accuracy. The controlled practice worksheets contained mathematical word problems similar to word problems found on experimenter-made baseline, acquisition, and maintenance probes. The word problems on the controlled practice worksheets were developed following the same procedures for the development of word problems for experimenter-made baseline, acquisition, and maintenance probes. Controlled practice worksheets consisted of six mathematical word problems.

Advanced practice worksheets were given to students after they reached an 80% mastery level on the controlled practice worksheets. Advanced practice worksheets contained mathematical word problems take from the Heath Mathematics: Levels 5 and 6 (Rucker, Dilley, & Lowery, 1988) basal mathematics series. Advanced practice worksheets consisted of six word problems.

Scoring Procedures of Instruments

The three instruments were scored with methods relative to the type of information that was obtained. The procedures for each instrument is discussed (see Table 14).

Table 14: Scoring of Instruments

Name of Instrument	Scoring Procedures
Pretest Screening Test	Screening Test - Subject obtains 85% or better accuracy of computing items on See-Write Precision Teaching Sheets developed by Orance County Public School Precision Teaching Project for inclusion in study.
Experimenter-Made BAM Probes	**Number of marks:** Total number of appropriate and inappropriate marks related to SIGNS strategy counted per 5 minute time period. For baseline, acquisition, and maintenance phases. **Number problems correctly and incorrectly solved**: Total number of problems attempted by subject is counted per 5 minute time period.
Experimenter-Made Generalization (G)Probes	**Number of marks:** Total number of appropriate and inappropriate marks related to SIGNS strategy counted in a 5 minute time period. For generalization phase. **Number of problems correctly and incorrectly solved**: Total number of problems solved correctly and incorrectly by subject is counted for a 5 minute time period.

Prescreening Test

The Prescreening test was scored according to the computational accuracy of the prospective subjects. To qualify for participation in the study, subjects obtained an accuracy score of 85% or better. The criterion level of 85% was arbitrarily set to select students with above average computational skills in addition, subtraction, and multiplication of whole numbers.

Experimenter-Made Baseline, Acquisition, and Maintenance Probes

The experimenter-made baseline, acquisition, and maintenance (BAM) probes were scored across two areas. A rate measure was obtained with regard to the number of marks associated with the SIGNS made in 5 minutes. The SIGNS marks are written and observed and served as indicators showing the use of the strategy when solving word problems.

A second type of information that was obtained from the probes was the number of problems correctly and incorrectly solved by the subject. The number of problems correctly and incorrectly solved by the subject in 5 minutes was counted, recorded, and charted.

Experimenter-Made Generalization Probes

The experimenter-made generalization (G) probes were also scored in the same manner as the baseline, acquisition, and maintenance probes. The procedures are the same and the obtained measures were similar except that rate, and the number of problems correctly and incorrectly solved were reported for multistep word problems found on the generalization probes.

Experimental Design

A single subject research design was used and was considered to be appropriate for this study because the intervention procedures developed and applied are exploratory in nature (Peterson, 1987), and are similar to previous studies involving the application of the similar learning strategies instructional interventions (Hughes, 1985; Lenz, Schumaker, Deshler, & Beals, 1984).

The type of single subject methodology used in this study was a multiple probe design (Horner & Baer, 1978) across subjects (Tawney & Gast, 1984). The multiple probe design across subjects was implemented to control for an extended baseline that controlled for possible practice effects on the probes by the subjects, subject fatigue, and subject frustration.

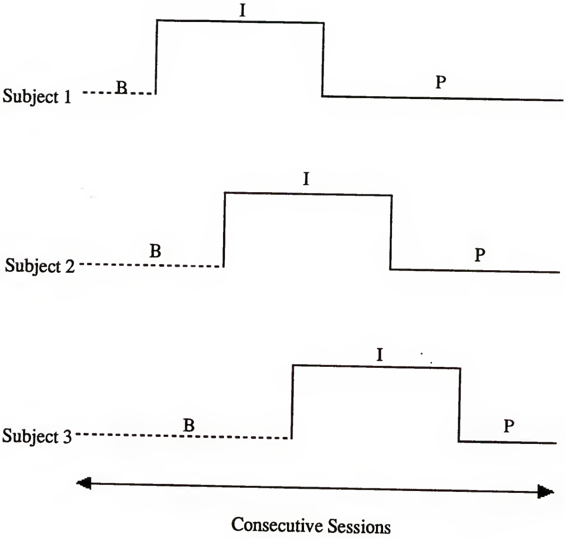
The multiple probe design has three practical advantages over a traditional multiple baseline design (Tawney & Gast, 1984). They stated that the multiple probe design may be more "appropriate than a multiple baseline design when prolonged baseline measures are either unnecessary, reactive or impractical" (p. 272). Horner and Baer (1978) supported the use of the multiple probe design in situations in which the subject was unable to master the target behaviors before provided with instruction. Cuvo (1979) also supported the use of the multiple probe design in situations in which the "baseline level is low or when there is no opportunity for subjects to acquire the target response(s) without direct training" (p. 222). The experimental design is represented in Figure 1.

The study was divided into two components. The first component consists of three phases: a baseline phase, an intervention phase, and a posttreatment phase.(see Figure 1).

Baseline phase

During the baseline phase, mixed probes containing 18 word problems were administered to all subjects. The subjects were given 5 minutes to complete the probes. Information obtained from these probes included the number of SIGNS markings made by the student in 5 minutes, and the number of problems the subjects correctly and incorrectly solved.

When a stable baseline with regard to the three measures was obtained for the first set of subjects, treatment procedures involving the acquisition of the SIGNS strategy were initiated. When the first set of subjects reached proficiency in the use of the strategy (70 percent mastery level), or data points appeared to be on a positive rising trend, baseline data were collected on the second set of subjects and the intervention procedures were instituted. Upon mastery of the SIGNS procedures by the second set of subjects, or evidence of a positive rising trend was exhibited, baseline data were collected on the remaining subjects. Once baseline data were collected, the intervention was initiated on the last subjects .



Note: ——— = Independent variable in contact with subject
- - - - = Independent variable not in contact with subject
| = Beginning of a new phase
B = Baseline phase
I = Intervention phase
P = Postintervention phase

Figure 1: Diagram of Experimental Design

During the administrations of the mixed probes to subjects, teacher and experimenter feedback regarding subjects' performances was withheld. The data were entered and recorded on standard 6-cycle behavior charts. Baseline data were gathered for a minimum of 3 days (Tawney & Gast, 1984).

Intervention phase

During the intervention phase, the subjects were taught to solve mathematical word problems using the SIGNS Word Problem-Solving strategy. The procedures were scripted for the teacher to use for instructing the subjects.

The procedures consisted of the teacher describing and modeling the strategy for the students using addition, subtraction, and multiplication mathematical word problems. The procedures also required the subjects to practice verbally the steps of the strategy until the subjects obtained a 100 percent mastery level.

After subjects mastered the strategy verbally, practice applying the strategy to worksheets were initiated. The controlled practice worksheets contained six problems. An additional instructional procedure was implemented for providing elaborated feedback to the subjects regarding errors demonstrated on the practice worksheets.

After subjects received daily instruction and practice, BAM mixed probes were administered. Subjects were kept in this phase of acquisition until they were able to solve the problems on the probes with a 70% or better accuracy level. The students must demonstrate a 70% or better for 3 consecutive days before exiting the treatment phase.

Subjects unable to achieve a 70% or better on the probes but able to correctly solve the controlled practice problems with 80% or better accuracy level for 3 consecutive days, were given advanced practice in solving of word problems. Subjects were kept in this phase of treatment until they were able to demonstrate a 70% or better accuracy level on the BAM probes for 3 consecutive days.

Postintervention phase

After subjects demonstrated mastery in applying the strategy, generalization probes were administered to gauge whether subjects transferred the skills learned to the solving of multistep word problems. Generalization probes were administered to subjects for 3 consecutive sessions. Subjects who demonstrated competency in correctly solving 70% of the problems attempted were judged to have successfully generalized the strategy to new situations and were not provided further instruction in the problem-solving strategy. Students who were unable to obtain a 70% or better accuracy level on the solving of the multistep word problems were provided instruction designed to promote the generalization of the SIGNS strategy to multistep word problems.

During the postintervention phase, maintenance probes were intermittently administered to subjects. Subjects were also administered generalization probes after they achieved proficiency in solving multistep word problems to measure retention. Teachers were given latitude in the admistering of maintenance probes. Teachers were instructed to give probes after 3- to 4-days after the intervention had been terminated.

All three phases took place in the subjects' classrooms. A sequence of activities that occurred is presented in Table 15.

Data Analysis

The data collected was graphed and analyzed. A visual analysis (VA) of graphic data were conducted. The visual method of data analysis was selected because it can be used to evaluate individual or small group data and it is a dynamic process; data are continually collected and analyzed (Tawney & Gast, 1984). The visual method permitted the researcher to (a) make data-based decisions throughout a program, (b) focus on individual data patterns which facilitated individualized instruction, (c) discover new findings which may not have been directly related to the research question or program objective, and (d) allow other analysts to make independent conclusions about the effectiveness of the interventions used (Tawney & Gast, 1984).

Data were graphically represented on charts and were analyzed within conditions and between conditions for acquisition data and for generalization data to multistep problems data for all of the subjects. Level stability data were obtained by using procedures outlined by Tawney and Gast (1984) for determining stability. A 15% stability

Table 15 - Steps for implementation of experimental study

Step 1:	Administer Screening Instrument. Decide if student qualifies (85% or better) if Yes proceed to Step 2, if No do not proceed with participation.
Step 2:	Administer Experimenter-made probe to obtain baseline measures. When baseline is stable for first subject (S1) proceed to Step 3. Collect baseline probe data on other subjects. Chart all data obtained.
Step 3:	Begin instruction with S1. Chart data. Daily assess S1's ability to verbally state steps of SIGNS strategy. When S1 is able to verbally state SIGNS strategy with 100% accuracy for 3 separate trials, provided S1 with controlled practice materials. Administer probes to S1 to collect acquisition data. Chart data.When S1 reaches 90% mastery on controlled practice sheets for 3 consecutive days, but has failed to achieve 70% accuracy on probes, administer advanced practice sheets to S1.
Step 4:	Once S1 achieves 70% accuracy on probes, discontinue treatment. Collect baseline information on S2, and administer one probe to S3. Begin instruction with S2 and follow instruction of Step 3 with S2. Continue to collect baseline data on S3, acquisition data on S2, and maintenance data on S1.. Chart data.
Step 5:	When S1 is in maintenance condition, administer generalization probes. Chart information. If S1 achieves 70% accuracy on generalization probes, continue to administer maintenance and generalization probes periodically. If S1 fails to achieve 70% accuracy on generalization probes, implement generalization procedures.

Note: Once S2 is in Step 5 condition, begin instruction with S3 (Step 4 procedures).

criterion was used to determine level and trend stability. Trend direction was estimated by using the split-middle method (White & Haring, 1980) and trend stability from procedures presented by Tawney and Gast (1984). Trend and level information were obtained and reported.

Data were analyzed according to the rate of appropriate and inappropriate SIGNS markings made by the subjects, the numbers of problems correctly and incorrectly solved during baseline, intervention and maintenance phases. Generalization data were also analyzed to measure the rate of application of SIGNS markers to multistep word problems, and the number of multistep word problems correctly and incorrectly solved by the subjects.

CHAPTER IV

RESULTS

Introduction

The purpose of Chapter IV is to present the results of the experimental questions and procedural methods outlined in Chapter III. First, information related to interscorer reliability of the measurement probes is reported. Second, the interobserver agreement of instructional procedures exhibited by teacher participants is also reported. Third, each subject's individual data summaries for each research question investigated are also presented. Finally, summaries for the overall results for each of the questions are also discussed.

Interscorer Reliability

Three individuals scored 27 Baseline, Acquisition, and Maintenance (BAM) probes to obtain interscorer agreements. Each individual scored a total of 155 problems across ten areas (see Table 16). These areas were (a) appropriate marks for the S step of the SIGNS strategy, (b) inappropriate marks for the S step, (c) appropriate marks for the I step, (d) inappropriate marks for the I step, (e) appropriate marks for the G step, (f) inappropriate marks for the G step, (g) appropriate marks for the N step, (h) inappropriate marks for the N step, (i) appropriate marks for the

Table 16: Interscorer Reliabilities for 27 Baseline, Acquisition, and Maintenance (BAM) and Generalization (G) Probes

	S		I		G		N		S	
Agreements	A	I	A	I	A	I	A	I	A	I
Number	150	144	148	110	149	149	151	151	136	136
Percentage	96.8	92.9	95.5	71.0	96.1	96.1	97.4	97.4	87.7	87.7
Nonagreements										
Number	5	11	7	45	6	6	4	4	19	19
Percentage	3.2	7.1	4.5	29.0	3.9	3.9	2.6	2.6	12.3	12.3

Total Number of Opportunities	1550		
Total Number of Agreements	1424	Percentage of Agreement	91.9
Total Number of Nonagreements	126	Percentage of Nonagreement	8.1

Note: A: Appropriate Marks; I: Inappropriate Marks second S step, and (j) inappropriate marks for the second S step of the SIGNS strategy. Overall interscorer agreement was 91.9% and nonagreement was 8.1% out of 1550 opportunities for agreement.

Interobserver Agreement of Instructional Procedures

An interval recording system was implemented to measure participating teachers' instructional behaviors when teaching the word problem solving strategy to their students. Interval agreement was calculated by using the interval by interval method (Tawney & Gast, 1984). Participating teachers were observed on five occasions for 10-minute periods. A total of 100 intervals were used to measure each teacher's behaviors. The overall interobserver agreement for the three teachers in this study was 96.9%. Individual scores for each component measured are presented in Table 17.

Table 17: Interobserver Agreement on Instructional Procedures

Teacher	Script	Sequence	Pacing	Materials	Total Percentage
1	95/100	100/100	94/100	100/100	389/400 = 97.3%
2	99/100	100/100	92/100	100/100	391/400 = 97.8%
3	97/100	96/100	90/100	100/100	383/400 = 95.8%

Overall Interobserver Agreement: 1163/1200 = 96.9%

Results for each of the experimental questions are presented. Results are presented in terms of the usage of appropriate and inappropriate SIGNS marks, and numbers of problems solved by the subjects. Each of these measures were used to answer the experimental questions.

1. Do students with mild disabilities acquire a mathematical problem solving strategy which includes direct and mnemonic instruction?

2. Do students with mild disabilities retain a mathematical problem solving strategy which includes direct and mnemonic instruction?

3. Do mildly disabled students generalize a mathematical problem solving strategy which includes direct and mnemonic instruction to the solving of multistep mathematical word problems?

Results for Question One for Subjects Regarding the Acquisition of a Mathematical Word Problem Solving Strategy

Subject 1

Subject 1 was a 13 year old, eighth-grade, African-American female with a reported I.Q. of 92, reading grade level of 5.0, and a mathematics grade level of 6.5. Baseline condition was 3 days and intervention condition was 12 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 2. Table 18 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 3. Table 19 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S1 was +37. The median level for inappropriate marks for the same period was -22. There were no changes in level stabilities between baseline and intervention conditions for appropriate and inappropriate marks. There was no overlap between conditions for both types of marks (see Table 18).

The median level of problems correct for the comparisons between baseline and intervention was +1.5, and -15, for incorrect problems (see Table 19). The level stability comparing baseline and intervention for correct and incorrect problems changed from stable to variable. The percentage of data points that overlapped for correct problems was 41.6% and 0% for incorrect problems.

Comparison of trend changes using trend lines between conditions

There were no trend comparisons made. The insufficient numbers of data points obtained during the baseline conditions resulted in the unavailability of a trend to be predicted. The absence of trend information for the baseline phase made a comparison

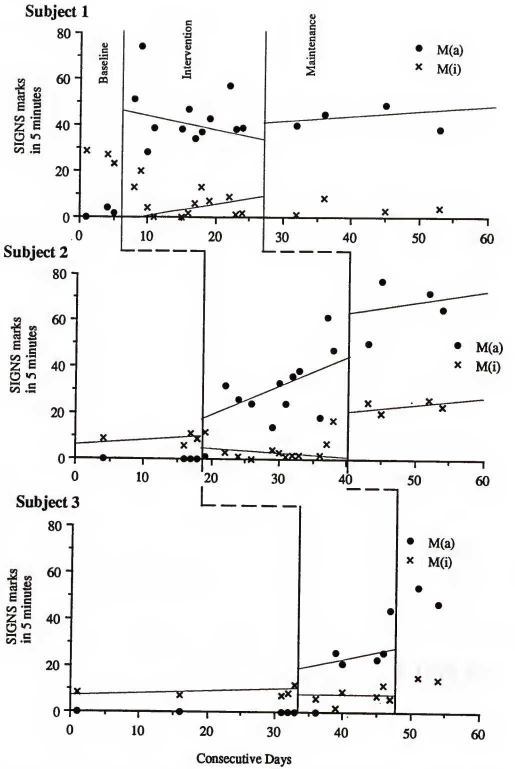


Figure 2 Number of appropriate (M(a)) and inappropriate marks (M(i)) made in 5 minutes by Subjects 1, 2, and 3.

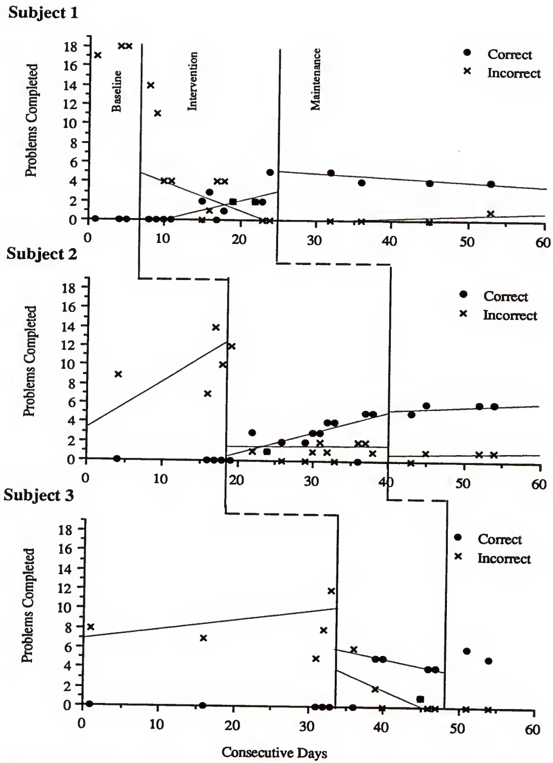


Figure 3 Number of problems completed in 5 minutes by Subjects 1, 2, and 3.

Table 18: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 2 for Subject 1: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	3	12	4/30	-	-	3	12	4/30	-	-
Median Level	2	39	42.5	+37	+3.5	27	5	3.5	-22	-1.5
Level Stability &	V	V	V	none	none	V	V	V	none	none
Range	(0-4)	(28-74)	(38-49)	0*	100*	(23-29)	(0-20)	(1-8)	0*	100*
Trend Direction#	-	$(-)^9$	$(=)^2$	-	- → =	-	$(+)^2$	$(-)^3$	-	+ → -
Trend Stability	-	V	V	-	none	-	V	V	-	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data path;
#/#: Number of measures/ Length of entire phase

Table 19: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 3 for Subject 1: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	3	12	4/30	-	-	3	12	4/30	-	-
Median Level	0	1.5	4	+1.5	+2.5	18	3	0	-15	-3
Level Stability &	S	V	V	S→V	none	S	V	V	S→V	none
Range	(0-1)	(0-5)	(4-5)	41.6*	100*	(17-18)	(0-14)	(0-1)	0*	100*
Trend Direction#	-	$(+)^4$	$(-)^1$	-	+ → -	-	$(-)^3$	$(+)^1$	-	- → +
Trend Stability	-	V	V	-	none	-	V	V	-	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths,
#/#: Number of measures/ Length of entire phase

between baseline and intervention condition trends for all variables impossible.

Subject 2

Subject 2 was a 13 year old, seventh-grade, African-American male with a reported I.Q. of 90, reading grade level of 4.6, and a mathematics grade level of 6.5. Baseline condition was 4 days and intervention condition was 12 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 2. Table 20 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 3. Table 21 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S2 was +29. The median level for inappropriate marks for the same period was -6.5. There was a level change in stability for appropriate marks between baseline and intervention conditions. Levels stability went from stable to variable. For inappropriate marks, there was no change in level stability. There was a 100% overlap between conditions for appropriate marks, and 83% overlap for inappropriate marks (see Table 20).

Table 20: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 2 for Subject 2: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within			Between		Within			Between	
	Condition			Change		Condition			Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	4	12	4/16	-	-	4	12	4/16	-	-
Median Level	0	29	68.5	+29	+39.5	9	2.5	24	-6.5	+22.5
Level Stability &	S	V	V	S→V	none	V	V	V	none	none
Range	(0-0)	(1-61)	(50-77)	100*	25*	(6-11)	(10-17)	(20-26)	83*	0*
Trend Direction#	$(=)^1$	$(+)^8$	$(-)^2$	= → +	+ → -	$(+)^3$	$(-)^4$	$(=)^3$	+ → -	- → =
Trend Stability	S	V	V	S→V	none	V	V	V	none	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths,
#/#: Number of measures/ Length of entire phase

Table 21: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 3 for Subject 2: Problems Solved

	Problems Correct					Problems Incorrect				
	Within			Between		Within			Between	
	Condition			Change		Condition			Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	4	12	4/16	-	-	4	12	4/16	-	-
Median Level	0	3	6	+3	+3	9.5	1	1	-8.5	0
Level Stability &	S	V	V	S→V	none	V	V	V	none	none
Range	(0-0)	(0-5)	(5-6)	16.6*	25*	(7-14)	(0-12)	(0-1)	8.3*	100*
Trend Direction#	(=)^1	(+)^5	(=)^1	= → +	+ → =	(+)^3	(=)^6	(=)^1	+ → =	none
Trend Stability	S	V	V	S→V	none	V	V	V	none	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths,
#/#: Number of measures/ Length of entire phase

The median level of problems correct for the comparisons between baseline and intervention was +3, and -8.5, for incorrect problems (see Table 21). The level stability comparing baseline and intervention for correct problems changed from stable to variable. There was no change between baseline and intervention for incorrect problems. The percentage of data points that overlapped for correct problems was 16.6% and 8.3% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between baseline and intervention conditions resulted in a change of trend direction from level trend line to an accelerating line (see Figure 2). Trend stability also changed from stable to variable between the two conditions (see Table 20) for appropriate marks. No change in trend stability was noted for inappropriate marks. The trend direction changed from an accelerating direction to a decelerating direction when comparing inappropriate marks made between baseline and intervention conditions (see Figure 2).

A comparison of trends for problems solved correctly between baseline and intervention conditions resulted in a change of trend direction from a level trend to an accelerating trend line (see Figure 3). Trend stability also changed from stable to variable for problems solved correctly (see Table 21).

For problems solved incorrectly, the comparisons made between baseline and intervention conditions for trend direction resulted in a change in trend direction from a accelerating direction to a level trend (see Figure 3). There was no change in trend stability (see Table 21).

Subject 3

Subject 3 was a 13 year old, seventh-grade, African-American male with a reported I.Q. of 95, reading grade level of 4.6, and a mathematics grade level of 6.5. Baseline condition was 5 days and intervention condition was 6 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 2. Table 22 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 3. Table 23 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S3 was +25. The median level for inappropriate marks for the same period was -1.5. There was a level change in stability for appropriate marks between baseline and intervention conditions. Levels stability went from stable to variable. For inappropriate marks, there was no change in level stability. There was a 16.6% overlap between

Table 22: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 2 for Subject 3: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	5	6	2/7	-	-	5	6	2/7	-	-
Median Level	0	25	50.5	+25	+25.5	8	6.5	14.5	-1.5	+8
Level Stability &	S	V	S	S→V	V→S	V	V	S	V→S	V→S
Range	(0-0)	(1-44)	(47-54)	16.6*	0*	(7-12)	(2-12)	(14-15)	50*	0*
Trend Direction#	$(=)^1$	$(+)^3$	-	= → +	-	$(=)^2$	$(=)^5$	-	none	-
Trend Stability	S	V	-	S→V	-	V	V	-	none	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating; (-): Decelerating; (=): Level or no change; #: Number of data paths, #/#: Number of measures/ Length of entire phase

Table 23: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 3 for Subject 3: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	5	6	2/7	-	-	5	6	2/7	-	-
Median Level	0	4	5.5	+4	+1.5	8	.5	0	-7.5	-0.5
Level Stability &	S	V	V	S→V	none	V	V	S	none	V→S
Range	(0-0)	(0-5)	(5-6)	16.6*	50*	(5-12)	(0-6)	(0-0)	16.6*	100*
Trend Direction#	(=)^{1}	(-)^{3}	-	= → -	-	(+)^{2}	(-)^{3}	-	+ → -	-
Trend Stability	S	V	-	S→V	-	V	V	-	none	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths,
#/#: Number of measures/ Length of entire phase

conditions for appropriate marks, and 50% overlap for inappropriate marks (see Table 22).

The median level of problems correct for the comparisons between baseline and intervention was +4, and -7.5, for incorrect problems (see Table 23). The level stability comparing baseline and intervention for correct problems changed from stable to variable. There was no change between baseline and intervention for incorrect problems. The percentage of data points that overlapped for correct problems was 16.6% and 16.6% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between baseline and intervention conditions resulted in a change of trend direction from level trend line to an accelerating line (see Figure 2). Trend stability also changed from stable to variable between the two conditions (see Table 22). The trend direction stayed level when a comparison was made between baseline and intervention conditions for inappropriate marks (see Figure 2).

A comparison of trends for problems solved correctly between baseline and intervention conditions resulted in a change of trend direction from a level trend to an decelerating trend line (see Figure 3). Trend stability also changed from stable to variable for problems solved correctly (see Table 23).

For problems solved incorrectly, the comparisons made between baseline and intervention conditions for trend direction resulted in a change in trend direction from a accelerating direction to a decelerating trend (see Figure 3). There was no change in trend stability (see Table 23).

Subject 4

Subject 4 was a 14 year old, eighth-grade, African-American male with a reported I.Q. of 93, reading grade level of 3.9, and a mathematics grade level of 5.3. Baseline condition was 5 days and intervention condition was 6 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 4. Table 24 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 5. Table 25 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S4 was +44. The median level for inappropriate marks for the same period was -6.5. There was no change in level stability for appropriate marks and inappropriate marks between baseline and intervention conditions. There was a 16.6% overlap between conditions for appropriate marks, and 16.6% overlap for inappropriate marks (see Table 24).

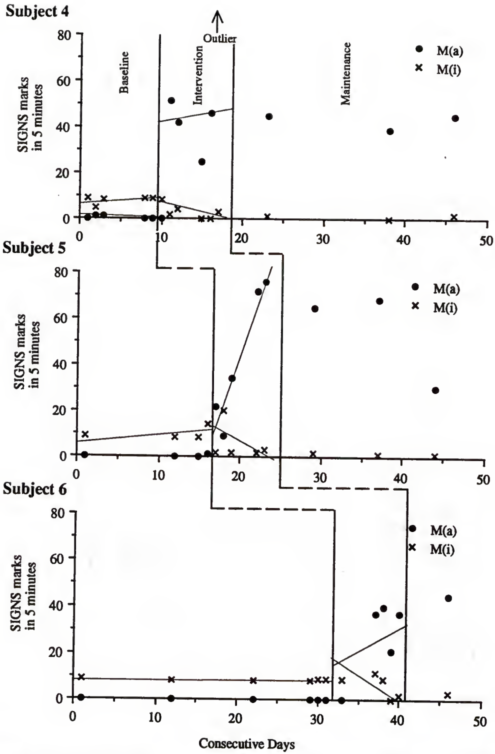


Figure 4 Number of appropriate (M(a)) and inappropriate (M(i)) marks made in 5 minutes by Subjects 4, 5, and 6.

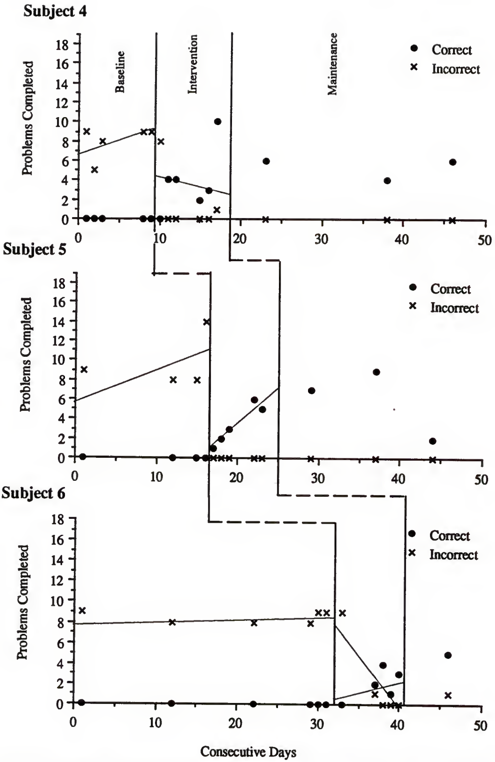


Figure 5 Number of problems completed in 5 minutes by Subjects 4, 5, and 6.

Table 24: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 4 for Subject 4: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	5	6	3/30	-	-	5	6	3/30	-	-
Median Level	0	44	45	+44	+1	9	2.5	1	-6.5	-1.5
Level Stability &	V	V	V	none	none	V	V	V	none	none
Range	(0-1)	(0-105)	(39-45)	16.6*	100*	(5-9)	(0-8)	(0-2)	16.6*	100*
Trend Direction#	(-)^2	(+)^3	-	- → +	-	(+)^3	(-)^4	-	+ → -	-
Trend Stability	V	V	-	none	-	V	V	-	none	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

Table 25: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 5 for Subject 4: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	5	6	3/30	-	-	5	6	3/30	-	-
Median Level	0	3.5	6	+3.5	+2.5	9	0	0	-9	0
Level Stability &	S	V	V	S→V	none	V	V	S	none	V→S
Range	(0-0)	(0-10)	(4-6)	16.6*	100*	(5-9)	(0-8)	(0-0)	16.6*	100*
Trend Direction#	$(=)^1$	$(-)^3$	-	= → -	-	$(+)^2$	$(=)^3$	-	+ → =	-
Trend Stability	S	V	-	S→V	-	V	V	-	none	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating; (-): Decelerating; (=): Level or no change; #: Number of data paths; #/#: Number of measures/ Length of entire phase

The median level of problems correct for the comparisons between baseline and intervention was +3.5, and -9, for incorrect problems (see Table 25). The level stability comparing baseline and intervention for correct problems changed from stable to variable. There was no change between baseline and intervention for incorrect problems. The percentage of data points that overlapped for correct problems was 16.6% and 16.6% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between baseline and intervention conditions resulted in a change of trend direction from decelerating trend line to an accelerating line (see Figure 4). There was no change in trend stability between conditions for appropriate marks(see Table 24). A change in direction, accelerating during baseline to decelerating during intervention was noted for inappropriate marks (see Figure 4).

A comparison of trends for problems solved correctly between baseline and intervention conditions resulted in a change of trend direction from a level trend to an decelerating trend line (see Figure 5). Trend stability also changed from stable to variable for problems solved correctly (see Table 25).

For problems solved incorrectly, the comparisons made between baseline and intervention conditions for trend direction resulted in a change in trend direction from a accelerating direction to a decelerating trend (see Figure 5). There was no change in trend stability (see Table 25).

Subject 5

Subject 5 was a 13 year old, eighth-grade, Caucasian male with a reported I.Q. of 91, reading grade level of 5.4, and a mathematics grade level of 5.5. Baseline condition was 4 days and intervention condition was 5 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 4. Table 26 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 5. Table 27 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S5 was +34. The median level for inappropriate marks for the same period was -6.5. There was no change in level stability for appropriate marks and inappropriate marks between baseline and intervention conditions. There was a 0% overlap between conditions for appropriate marks, and 0% overlap for inappropriate marks (see Table 26).

Table 26: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 4 for Subject 5: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	4	5	3/23	-	-	4	5	3/23	-	-
Median Level	0	34	65	+34	+31	8.5	2	1	-6.5	-1
Level Stability &	V	V	V	none	none	V	V	V	none	none
Range	(0-1)	(9-76)	(30-68)	0*	100*	(8-14)	(2-20)	(1-2)	0*	33.3*
Trend Direction#	(=)^2	(+)^2	-	= →+	-	(+)^2	(-)^3	-	+ → -	-
Trend Stability	V	V	-	none	-	V	V	-	none	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating; (-): Decelerating; (=): Level or no change; #: Number of data paths; #/#: Number of measures/ Length of entire phase

Table 27: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 5 for Subject 5: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	4	5	3/23	-	-	4	5	3/23	-	-
Median Level	0	3	7	+3	+4	8.5	0	0	-8.5	0
Level Stability &	S	V	V	S→V	none	V	S	S	V→S	none
Range	(0-0)	(1-6)	(2-9)	0*	33*	(8-14)	(0-0)	(0-0)	0*	100*
Trend Direction#	(=)^1	(+)^2	-	= → +	-	(+)^3	(=)^1	-	+ → =	-
Trend Stability	S	V	-	S→V	-	V	S	-	V→S	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

The median level of problems correct for the comparisons between baseline and intervention was +3, and +8.5, for incorrect problems (see Table 27). The level stability comparing baseline and intervention for correct problems changed from stable to variable, and from variable to stable for incorrect problems. The percentage of data points that overlapped for correct problems was 0% and 0% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between baseline and intervention conditions resulted in a change of trend direction from a level trend line to a quickly accelerating line (see Figure 4). There was no change in trend stability between conditions for appropriate marks(see Table 26). A change in direction, accelerating during baseline to decelerating during intervention was noted for inappropriate marks (see Figure 4).

A comparison of trends for problems solved correctly between baseline and intervention conditions resulted in a change of trend direction from a level trend to an accelerating trend line (see Figure 5). Trend stability also changed from stable to variable for problems solved correctly (see Table 27).

For problems solved incorrectly, the comparisons made between baseline and intervention conditions for trend direction resulted in a change in trend direction from an accelerating direction to a level trend line (see Figure 5). There was no change in trend stability (see Table 27).

Subject 6

Subject 6 was a 14 year old, eighth-grade, Caucasian male with a reported I.Q. of 97, reading grade level of 5.4, and a mathematics grade level of 6.6. Baseline condition was 6 days and intervention condition was 5 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 4. Table 28 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 5. Table 29 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S6 was +37. The median level for inappropriate marks for the same period was +0.5. There was level stability for appropriate marks and inappropriate marks between baseline and intervention conditions changed from stable to variable. There was a 20% overlap between conditions for appropriate marks, and 40% overlap for inappropriate marks (see Table 28).

Table 28: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 4 for Subject 6: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	6	5	1/7	-	-	6	5	1/7	-	-
Median Level	0	37	45	+37	+8	8.5	9	3	+0.5	-6
Level Stability &	S	V	-	S→V	-	S	V	-	S→V	-
Range	(0-0)	(0-40)	(45)	20*	0*	(8-9)	(0-12)	(3)	40*	100*
Trend Direction#	$(=)^1$	$(+)^3$	-	= → +	-	$(=)^1$	$(-)^3$	-	= → -	-
Trend Stability	S	V	-	S→V	-	S	V	-	S→V	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

Table 29: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 5 for Subject 6: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	6	5	1/7	-	-	6	5	1/7	-	-
Median Level	0	2	5	+2	+3	8.5	0	1	-8.5	+1
Level Stability &	S	V	-	S→V	-	S	V	-	S→V	-
Range	(0-0)	(0-4)	(5)	20*	0*	(8-9)	(0-9)	(1)	20*	100*
Trend Direction#	(=)^1	(+)^3	-	= → +	-	(=)^1	(-)^2	-	= → -	-
Trend Stability	S	V	-	S→V	-	S	V	-	S→V	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating; (-): Decelerating; (=): Level or no change; #: Number of data paths; #/#: Number of measures/ Length of entire phase

The median level of problems correct for the comparisons between baseline and intervention was +2, and +8.5, for incorrect problems (see Table 29). The level stability comparing baseline and intervention for correct and incorrect problems changed from stable to variable. The percentage of data points that overlapped for correct problems was 20% and 20% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between baseline and intervention conditions resulted in a change of trend direction from a level trend line to a quickly accelerating line (see Figure 4). There was a change in trend stability between conditions for appropriate and inappropriate marks from stable to variable (see Table 28). A change in direction, level during baseline to decelerating during intervention was noted for inappropriate marks (see Figure 4).

A comparison of trends for problems solved correctly between baseline and intervention conditions resulted in a change of trend direction from a level trend to an accelerating trend line (see Figure 5). Trend stability also changed from stable to variable for problems solved correctly (see Table 29).

For problems solved incorrectly, the comparisons made between baseline and intervention conditions for trend direction resulted in a change in trend direction from a level trend to a decelerating trend line (see Figure 5). Trend stability also changed from stable to variable (see Table 29).

Subject 7

Subject 7 was a 13 year old, seventh-grade, African-American male with a reported I.Q. of 87, reading grade level of 4.0, and a mathematics grade level of 4.6. Baseline condition was 4 days and intervention condition was 8 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 6. Table 30 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 7. Table 31 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S7 was +35. The median level for inappropriate marks for the same period was -3. There was a change in level stability for appropriate marks from stable to variable. For inappropriate marks, there was no change in level stability between baseline and intervention conditions. There was a 25% overlap between conditions for appropriate marks, and 50% overlap for inappropriate marks (see Table 30).

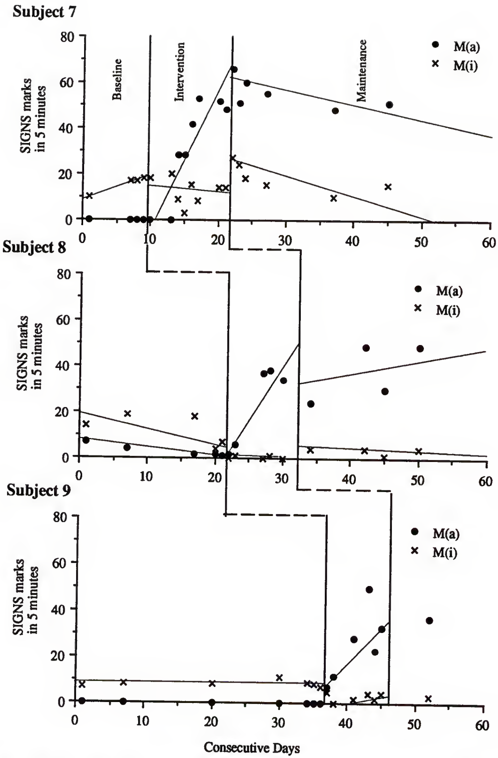


Figure 6 Number of appropriate (M(a)) and inappropriate (M(i)) marks made in 5 minutes by Subjects 7, 8, and 9.

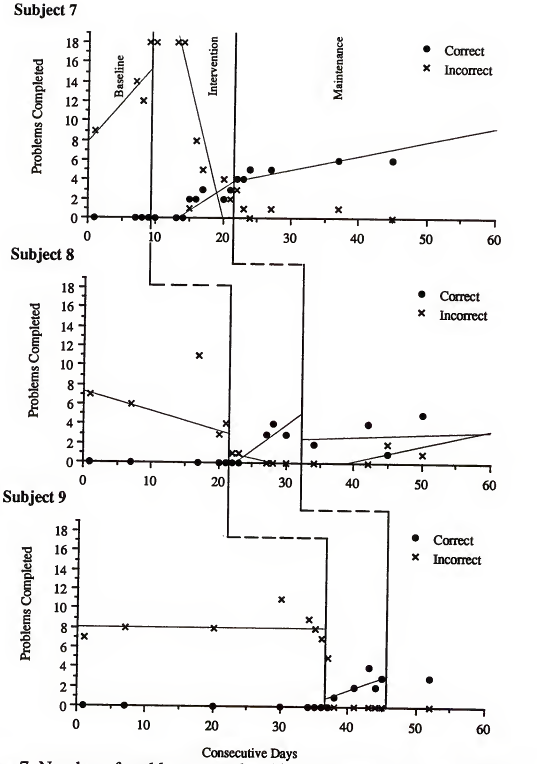


Figure 7 Number of problems completed in 5 minutes by Subjects 7, 8, and 9.

Table 30: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 6 for Subject 7: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	4	8	6/38	-	-	4	8	6/38	-	-
Median Level	0	35	53	+35	+18	17	14	16.5	-3	+2.5
Level Stability &	S	V	V	S→V	none	V	V	V	none	none
Range	(0-0)	(0-53)	(48-66)	25*	50*	(10-18)	(3-20)	(10-27)	50*	66.6*
Trend Direction#	$(=)^1$	$(+)^4$	$(-)^4$	= → +	+ → -	$(+)^1$	$(=)^5$	$(-)^2$	+ → =	= → -
Trend Stability	S	V	V	S→V	none	V	V	V	none	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

Table 31: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 7 for Subject 7: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	4	8	6/38	-	-	4	8	6/38	-	-
Median Level	0	2	5	+2	+3	13	6.5	1	-7.5	-5.5
Level Stability &	S	V	V	S→V	none	V	V	V	none	none
Range	(0-0)	(0-3)	(4-6)	37.5*	0*	(9-18)	(1-18)	(0-3)	37.5*	66.6*
Trend Direction#	$(=)^1$	$(+)^4$	$(+)^2$	= → +	none	$(+)^3$	$(-)^4$	$(-)^4$	+ → -	none
Trend Stability	S	V	V	S→V	none	V	V	V	none	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

The median level of problems correct for the comparisons between baseline and intervention was +2, and -7.5, for incorrect problems (see Table 31). The level stability comparing baseline and intervention for correct problems changed from stable to variable, and no change in level for incorrect problems. The percentage of data points that overlapped for correct problems was 37.5% and 37.5% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between baseline and intervention conditions resulted in a change of trend direction from a level trend line to a quickly accelerating line (see Figure 6). There was a change in trend stability between conditions for appropriate marks from stable to variable (see Table 30). A change in direction, accelerating during baseline to decelerating during intervention was noted for inappropriate marks (see Figure 6).

A comparison of trends for problems solved correctly between baseline and intervention conditions resulted in a change of trend direction from a level trend to an accelerating trend line (see Figure 7). Trend stability also changed from stable to variable for problems solved correctly (see Table 31).

For problems solved incorrectly, the comparisons made between baseline and intervention conditions for trend direction resulted in a change in trend direction from an accelerating direction to a rapidly decelerating trend line (see Figure 7). There was no change in trend stability (see Table 31).

Subject 8

Subject 8 was a 13 year old, seventh-grade, African-American male with a reported I.Q. of 94, reading grade level of 3.5, and a mathematics grade level of 4.2. Baseline condition was 5 days and intervention condition was 5 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 6. Table 32 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 7. Table 33 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S8 was +32. The median level for inappropriate marks for the same period was -14. There was no change in level stability for appropriate marks. For inappropriate marks, there was no change in level stability between baseline and intervention conditions. There was a 40% overlap between conditions for appropriate marks, and 0% overlap for inappropriate marks (see Table 32).

Table 32: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 6 for Subject 8: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	5	5	4/21	-	-	5	5	4/21	-	-
Median Level	2	34	39.5	+32	+5.5	14	0	4	-14	+4
Level Stability &	V	V	V	none	none	V	V	V	none	none
Range	(1-7)	(2-38)	(24-49)	40*	50*	(4-19)	(0-1)	(1-4)	0*	25*
Trend Direction#	(-)^1	(+)^2	(+)^3	- → +	none	(-)^4	(-)^4	(-)^3	none	none
Trend Stability	V	V	V	none	none	V	V	V	none	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

Table 33: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 7 for Subject 8: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	5	5	4/21	-	-	5	5	4/21	-	-
Median Level	0	3	3	+3	0	6	0	0.5	+6	-0.5
Level Stability &	S	V	V	S→V	none	V	V	V	none	none
Range	(0-0)	(0-4)	(1-5)	40*	75*	(3-11)	(0-1)	(0-2)	0*	75*
Trend Direction#	$(=)^1$	$(+)^3$	$(=)^3$	= → +	+→=	$(-)^4$	$(-)^1$	$(+)^3$	none	- → +
Trend Stability	S	V	V	S→V	none	V	V	V	none	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

The median level of problems correct for the comparisons between baseline and intervention was +3, and -6, for incorrect problems (see Table 33). The level stability comparing baseline and intervention for correct problems changed from stable to variable, and no change in level for incorrect problems. The percentage of data points that overlapped for correct problems was 40% and 0% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between baseline and intervention conditions resulted in a change of trend direction from a decelerating trend line to a quickly accelerating line (see Figure 6). There was no change in trend stability between conditions for appropriate marks (see Table 32). No change in direction for the trend line was noted for inappropriate marks (see Figure 6).

A comparison of trends for problems solved correctly between baseline and intervention conditions resulted in a change of trend direction from a level trend to an accelerating trend line (see Figure 7). Trend stability also changed from stable to variable for problems solved correctly (see Table 33).

For problems solved incorrectly, the comparisons made between baseline and intervention conditions for trend direction resulted in no change of direction of the trend line (see Figure 7). There was no change in trend stability (see Table 33).

Subject 9

Subject 9 was a 13 year old, eighth-grade, African-American male with a reported I.Q. of 95, reading grade level of 4.2, and a mathematics grade level of 5.8. Baseline condition was 7 days and intervention condition was 6 days.

Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 6. Table 34 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 7. Table 35 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S9 was +25.5. The median level for inappropriate marks for the same period was -5. There was a change in level stability for appropriate marks from stable to variable. For inappropriate marks, there was no change in level stability between baseline and intervention conditions. There was a 0% overlap between conditions for appropriate marks, and 0% overlap for inappropriate marks (see Table 34).

The median level of problems correct for the comparisons between baseline and intervention was +2, and -8, for incorrect

Table 34: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 6 for Subject 9: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	7	6	1/7	-	-	7	6	1/7	-	-
Median Level	0	25.5	37	+25.5	+11.5	8	3	3	+5	0
Level Stability &	S	V	-	S→V	-	V	V	-	none	-
Range	(0-0)	(7-50)	(31)	0*	100*	(7-11)	(0-5)	(3)	0*	100*
Trend Direction#	$(=)^1$	$(+)^3$	-	= → +	-	$(=)^3$	$(+)^4$	-	= → +	-
Trend Stability	S	V	-	S→V	-	V	V	-	none	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

Table 35: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 7 for Subject 9: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	7	6	1/7	-	-	7	6	1/7	-	-
Median Level	0	2	3	+2	+1	8	0	0	+8	0
Level Stability &	S	V	-	S→V	-	V	V	-	none	-
Range	(0-0)	(0-4)	(3)	16.6*	100*	(7-11)	(0-5)	(0)	0*	100*
Trend Direction#	$(=)^1$	$(+)^3$	-	= → +	-	$(=)^4$	$(=)^2$	-	none	-
Trend Stability	S	V	-	S→V	-	V	V	-	none	-

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

problems (see Table 35). The level stability comparing baseline and intervention for correct problems changed from stable to variable, and no change in level for incorrect problems. The percentage of data points that overlapped for correct problems was 16.6% and 0% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between baseline and intervention conditions resulted in a change of trend direction from a level trend line to a quickly accelerating line (see Figure 6). There was a change in trend stability between conditions for appropriate marks from stable to variable (see Table 34). A change in direction, level during baseline to a slowly accelerating trend line during intervention was noted for inappropriate marks (see Figure 6).

A comparison of trends for problems solved correctly between baseline and intervention conditions resulted in a change of trend direction from a level trend to an accelerating trend line (see Figure 7). Trend stability also changed from stable to variable for problems solved correctly (see Table 35).

For problems solved incorrectly, the comparisons made between baseline and intervention conditions for trend direction resulted in no change of direction of the trend line (see Figure 7). There was no change in trend stability (see Table 35).

Subject 10

Subject 10 was a 13 year old, seventh-grade, Caucasian male with a reported I.Q. of 95, reading grade level of 5.5, and a mathematics grade level of 6.2. Baseline condition was 3 days and intervention condition was 5 days.

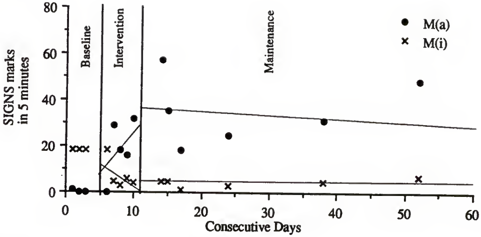
Data for appropriate and inappropriate marks and trend lines are displayed graphically in Figure 8. Table 36 contains a summary of the visual analysis of baseline and intervention data for appropriate and inappropriate marks. Data for problems solved correctly and incorrectly and trend lines are displayed in Figure 8. Table 37 contains a summary of the visual analysis of baseline and intervention data for problems solved correctly and incorrectly.

Comparison of median levels between conditions

The median level for the comparison between baseline and intervention for the numbers of appropriate marks made by S10 was +18. The median level for inappropriate marks for the same period was +13. There was no change in level stability for appropriate marks. For inappropriate marks, there was a change in level stability between baseline and intervention conditions from stable to variable. There was a 20% overlap between conditions for appropriate marks, and 20% overlap for inappropriate marks (see Table 36).

The median level of problems correct for the comparisons between baseline and intervention was 0, and +15, for incorrect

Subject 10



Subject 10

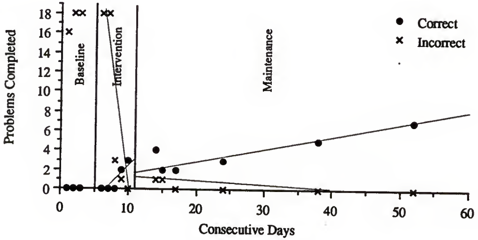


Figure 8 Acquisition and retention data for Subject 10.

Table 36: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 8 for Subject 10: Usage of SIGNS marks

	Appropriate Marks					Inappropriate Marks				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	3	5	6/42	-	-	3	5	6/42	-	-
Median Level	0	18	33	+18	+15	18	5	5	+13	0
Level Stability & Range	V (0-1)	V (0-32)	V (18-57)	none 20*	none 50*	S (18-18)	V (3-18)	V (1-7)	S→V 20*	none 66.6*
Trend Direction#	-	(+)^3	(-)^2	-	+ → -	-	(-)^3	(=)^2	-	- → =
Trend Stability	-	V	V	-	none	-	V	V	-	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

Table 37: Summary of Visual Analysis of Baseline (BL), Intervention (I), and Maintenance (M) Data Plotted in Figure 8 for Subject 10: Problems Solved

	Problems Correct					Problems Incorrect				
	Within Condition			Between Change		Within Condition			Between Change	
Analysis	BL	I	M	BL/I	I/M	BL	I	M	BL/I	I/M
Length (in days)	3	5	6/42	-	-	3	5	6/42	-	-
Median Level	0	0	3.5	0	+3.5	18	3	0	+15	+3
Level Stability & Range	S (0-0)	V (0-3)	V (2-7)	S→V 60*	none 50*	V (16-18)	V (0-18)	V (0-1)	none 40*	none 100*
Trend Direction#	-	$(+)^2$	$(+)^2$	-	none	-	$(-)^2$	$(-)^2$	-	none
Trend Stability	-	V	V	-	none	-	V	V	-	none

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ;
(-): Decelerating; (=): Level or no change; #: Number of data paths;
#/#: Number of measures/ Length of entire phase

problems (see Table 37). The level stability comparing baseline and intervention for correct problems changed from stable to variable, and no change in level for incorrect problems. The percentage of data points that overlapped for correct problems was 60% and 40% for incorrect problems.

Comparison of trend changes using trend lines between conditions

There were no trend comparisons made. The insufficient numbers of data points obtained during the baseline conditions resulted in the unavailability of a trend to be predicted. The absence of trend information for the baseline phase made a comparison between baseline and intervention condition trends for all variables impossible.

Summary of Overall Results for Question One

During the baseline condition, no subject made more than seven appropriate marks on the BAM probes (range 0-7). Subjects' writing of inappropriate marks was widely varied (range 4-29) during baseline conditions. During baseline conditions, one subject correctly solved one problem. All other subjects failed to correctly solve any of the problems presented on the BAM probes. Subjects did exhibit high levels of incorrect problem solving during baseline (range 3-18 incorrect problems).

During the intervention condition, subjects demonstrated competence in writing the appropriate marks associated with the SIGNS word problem strategy. One subject (Subject 4) started the intervention phase without making any appropriate marks on the first day, but by the sixth session he had written 105 appropriate marks when attempting to solve the problems on the BAM probes. Nine out of the 10 subjects exhibited an increasing trend in the demonstration of writing appropriate marks of the SIGNS strategy when solving word problems. While Subject 1 demonstrated a declining trend line for the number of appropriate marks written when attempting to solve the BAM probes, the level of appropriate marks were approximately four times higher than inappropriate marks written. The continued upward trend of appropriate marks of the SIGNS strategy showed that these students were able to acquire a strategy for solving mathematical word problems.

While it was important for the subjects to demonstrate that they had learned the steps of the strategy, the effectiveness of the application of the strategy to mathematical word problems was also shown. All ten of the subjects were able to correctly solve at least three BAM probe problems during the intervention phase. The range of problems solved correctly was from a low of three problems correct in 5 minutes to a high of 10 problems correct in 5 minutes. The difference in the problem solving ability of the subjects was dramatic after they had received instruction in the word problem solving strategy and had demonstrated that they had acquired the strategy. It was hypothesized that the subjects would acquire the problem solving strategy and that problems solving performance would be improved. The data showed that the hypothesis was valid.

Results for Individual Subjects Pertaining to Retention of a Mathematical Word Problem Solving Strategy

Subject 1

Intervention condition was in effect for 12 days and maintenance condition was in effect for 30 days. Four maintenance measures were obtained Intervention data and maintenance data have been previously displayed on Figures 2 and 3. The summary of the visual analysis of the data have been previously presented on Tables 18 and 19.

Comparison of median levels between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S1 was +3.5. The median level for inappropriate marks for the same period was -1.5. There were no changes in level stabilities between intervention and maintenance conditions for appropriate and inappropriate marks. There was a 100% overlap between conditions for both types of marks (see Table 18).

The median level of problems correct for the comparisons between intervention and maintenance was +2.5, and -3, for incorrect problems (see Table 19). The level stability comparing intervention and maintenance for correct and incorrect problems did not change. The percentage of data points that overlapped for correct problems was 100% and 100% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between intervention and maintenance conditions resulted in a change of trend direction from a decelerating trend line to a level trend line (see Figure 2). Trend stability did not change between the two conditions (see Table 18). The trend direction changed from an accelerating direction to a decelerating direction when comparing inappropriate marks made between intervention and maintenance conditions (see Figure 2).

A comparison of trends for problems solved correctly between intervention and maintenance conditions resulted in a change of trend direction from an accelerating trend to a decelerating trend line (see Figure 3). Trend stability was not changed for problems solved correctly (see Table 19).

For problems solved incorrectly, the comparisons made between intervention and maintenance conditions for trend direction resulted in a change in trend direction from a decelerating direction to a slight accelerating trend (see Figure 3). There was no change in trend stability (see Table 19)

Subject 2

Intervention condition was in effect for 12 days and maintenance condition was in effect for 16 days. Four maintenance measures were obtained. Intervention data and maintenance data have been previously displayed on Figures 2 and 3. The summary of the visual analysis of the data have been previously presented on Tables 20 and 21.

Comparison of median levels between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S2 was +39.5. The median level for inappropriate marks for the same period was +22.5. There was a level change in stability for appropriate marks between intervention and maintenance conditions. Levels stability went from stable to variable. For inappropriate marks, there was no change in level stability. There was a 25% overlap between conditions for appropriate marks, and 0% overlap for inappropriate marks (see Table 20).

The median level of problems correct for the comparisons between intervention and maintenance was +3, and 0, for incorrect problems (see Table 21). There was no change between intervention and maintenance for correct and incorrect problems. The percentage of data points that overlapped for correct problems was 125% and 100% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between intervention and maintenance conditions resulted in a change of trend direction from an accelerating line to a decelerating trend line (see

Figure 2). There was no change in the trend stabilities between conditions. The trend direction changed from an accelerating direction to a decelerating direction when comparing inappropriate marks made between intervention and maintenance conditions (see Figure 2).

A comparison of trends for problems solved correctly between intervention and maintenance conditions resulted in a change of trend direction from an accelerating trend line to a level trend line (see Figure 3). Trend stability was not changed for problems solved correctly (see Table 21).

For problems solved incorrectly, the comparisons made between intervention and maintenance conditions for trend direction resulted in a change in trend direction from a accelerating direction to a level trend (see Figure 3). There was no change in trend stability (see Table 21).

Subject 3

Intervention condition was in effect for 6 days and maintenance condition was in effect for 7 days. Two maintenance measures were obtained. Intervention data and maintenance data have been previously displayed on Figures 2 and 3. The summary of the visual analysis of the data have been previously presented on Tables 22 and 23.

Comparison of median levels between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S3 was +25.5. The median level for inappropriate marks for the same period was +8. There was a level change in stability for appropriate and inappropriate marks between intervention and maintenance conditions. Levels stability went from variable to stable. There was a zero percent overlap between conditions for appropriate marks,and inappropriate marks (see Table 22).

The median level of problems correct for the comparisons between intervention and maintenance was +1.5, and -0.5, for incorrect problems (see Table 23). There was no change between intervention and maintenance for incorrect problems. The level stability comparing intervention and maintenance for incorrect problems changed from variable to stable. The percentage of data points that overlapped for correct problems was 50% and 100% for incorrect problems.

Comparison of trend changes using trend lines between conditions

There were no trend comparisons made. The insufficient numbers of data points obtained during the maintenance conditions resulted in the unavailability of a trend to be predicted. The absence of trend information for the maintenance phase made a comparison between intervention and maintenance condition trends for all variables impossible.

Subject 4

Intervention condition was in effect for 6 days and maintenance condition was in effect for 30 days. Three maintenance measures were obtained. Intervention data and maintenance data have been previously displayed on Figures 4 and 5. The summary of the visual analysis of the data have been previously presented on Tables 24 and 25.

Comparison of median levels between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S4 was +1. The median level for inappropriate marks for the same period was -1.5. There was no change in level stability for appropriate marks and inappropriate marks between intervention and maintenance conditions. There was a 100% overlap between conditions for appropriate marks, and 100% overlap for inappropriate marks (see Table 24).

The median level of problems correct for the comparisons between intervention and maintenance was +2.5, and 0, for incorrect problems (see Table 25). There was no change in level stability for correct problems. Level stability changed between intervention and maintenance for incorrect problems from variable to stable. There was a 100% overlap for correct and incorrect problems.

Comparison of trend changes using trend lines between conditions

There were no trend comparisons made. The insufficient numbers of data points obtained during the maintenance condition resulted in the unavailability of a trend to be predicted. The absence of trend information for the maintenance phase made a comparison between intervention and maintenance condition trends for all variables impossible.

Subject 5

Intervention condition was in effect for 6 days and maintenance condition was in effect for 23 days. Three maintenance measures were obtained. Intervention data and maintenance data have been previously displayed on Figures 4 and 5. The summary of the visual analysis of the data have been previously presented on Tables 26 and 27.

Comparison of median level change between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S5 was +31. The median level for inappropriate marks for the same period was -1. There was no change in level stability for appropriate marks and inappropriate marks between intervention and maintenance conditions. There was a 100% overlap between conditions for appropriate marks, and 33.3% overlap for inappropriate marks (see Table 26).

The median level of problems correct for the comparisons between intervention and maintenance was +4, and 0, for incorrect problems (see Table 27). There was no change in level stability for problems solved correctly and incorrectly. The percentage of data points that overlapped for correct problems was 33% and 100% for incorrect problems.

Comparison of trend changes using trend lines between conditions

There were no trend comparisons made. The insufficient numbers of data points obtained during the maintenance condition resulted in the unavailability of a trend to be predicted. The absence of trend information for the maintenance phase made a comparison between intervention and maintenance condition trends for all variables impossible.

Subject 6

Intervention condition was in effect for 5 days and maintenance condition was in effect for 7 days. One maintenance measure was obtained. Intervention data and maintenance data have been previously displayed on Figures 4 and 5. The summary of the visual analysis of the data have been previously presented on Tables 28 and 29.

Comparison of median levels between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S6 was +8. The median level for inappropriate marks for the same period was -6. Level stability was not compared because of only 1 data point in the maintenance condition. There was a 20% overlap between conditions for appropriate marks, and 100% overlap for inappropriate marks (see Table 28).

The median level of problems correct for the comparisons between intervention and maintenance was +3, and +1, for incorrect problems (see Table 29). Level stability was not compared because of only 1 data point in the maintenance condition. The percentage of data points that overlapped for correct problems was 0% and 100% for incorrect problems.

Comparison of trend changes using trend lines between conditions

There were no trend comparisons made. The insufficient numbers of data points obtained during the maintenance condition resulted in the unavailability of a trend to be predicted. The absence of trend information for the maintenance phase made a comparison between intervention and maintenance condition trends for all variables impossible.

Subject 7

Intervention condition was in effect for 8 days and maintenance condition was in effect for 38 days. Six maintenance measures were obtained. Intervention data and maintenance data have been previously displayed on Figures 6 and 7. The summary of the visual analysis of the data have been previously presented on Tables 30 and 31.

Comparison of median levels between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S7 was +18. The median level for inappropriate marks for the same period was +2.5. For appropriate and inappropriate marks, there was no change in level stability between intervention and maintenance conditions. There was a 50% overlap between conditions for appropriate marks, and 66.6% overlap for inappropriate marks (see Table 30).

The median level of problems correct for the comparisons between intervention and maintenance was +3, and -5.5, for incorrect problems (see Table 31). No change in level for correct and incorrect problems were noted. The percentage of data points that overlapped for correct problems was 0% and 66.6% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between intervention and maintenance conditions resulted in a change of trend direction from an accelerating line to a decelerating trend line (see Figure 6). There was no change in trend stability between conditions for appropriate marks (see Table 30). A change in direction, accelerating during intervention to a level line during maintenance was noted for inappropriate marks (see Figure 6).

A comparison of trends for problems solved correctly between intervention and maintenance conditions resulted in no change of trend direction (see Figure 7). Trend stability also did not change for problems solved correctly (see Table 31).

For problems solved incorrectly, the comparisons made between intervention and maintenance conditions for trend direction resulted in a continued decelerating trend line (see Figure 7). There was no change in trend stability (see Table 31).

Subject 8

Intervention condition was in effect for 5 days and maintenance condition was in effect for 21 days. Four maintenance measures were obtained. Intervention data and maintenance data have been previously displayed on Figures 6 and 7. The summary of the visual analysis of the data have been previously presented on Tables 32 and 33.

Comparison of median levels between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S8 was +5.5. The median level for inappropriate marks for the same period was +4. There was no change in level stability for appropriate marks or for inappropriate marks. There was a 50% overlap between conditions for appropriate marks, and 25% overlap for inappropriate marks (see Table 32).

The median level of problems correct for the comparisons between intervention and maintenance was 0, and +0.5, for incorrect problems (see Table 33). No change in level for correct and incorrect problems was noted. The percentage of data points that overlapped for correct and incorrect problems was 75%.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between intervention and maintenance conditions resulted in a continued accelerating trend line (see Figure 6). There was no change in trend stability between conditions for appropriate marks (see Table 32). No change in direction for the trend line was noted for inappropriate marks (see Figure 6). The trend line continued decelerate.

A comparison of trends for problems solved correctly between intervention and maintenance conditions resulted in a change of trend direction from an accelerating trend line to a level trend line (see Figure 7). No change in trend stability was noted (see Table 33).

For problems solved incorrectly, the comparisons made between intervention and maintenance conditions for trend direction resulted in a change of direction of the trend line from a decelerating trend line to an accelerating trend line (see Figure 7). There was no change in trend stability (see Table 33).

Subject 9

Intervention condition was in effect for 6 days and maintenance condition was in effect for 7 days. One maintenance measure was obtained.Intervention data and maintenance data have been previously displayed on Figures 4 and 5. The summary of the visual analysis of the data have been previously presented on Tables 34 and 35.

Comparison of median levels between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S9 was +11.5. The median level for inappropriate marks for the same period was 0. A level stability change was not conducted due to the presence of only 1 data point obtained during the maintenance condition. There was a 100% overlap between conditions for appropriate marks, and 100% overlap for inappropriate marks (see Table 34).

The median level of problems correct for the comparisons between intervention and maintenance was +1, and 0, for incorrect problems (see Table 31). The percentage of data points that overlapped for correct problems was 100% and 100% for incorrect problems (see Table 35).

Comparison of trend changes using trend lines between conditions

There were no trend comparisons made. The insufficient numbers of data points obtained during the maintenance conditions resulted in the unavailability of a trend to be predicted. The absence of trend information for the maintenance phase made a comparison between maintenance and intervention condition trends for all variables impossible.

Subject 10

Intervention condition was in effect for 5 days and maintenance condition was in effect for 42 days. Six maintenance measures were obtained. Intervention data and maintenance data have been previously displayed on Figures 4 and 5. The summary of the visual analysis of the data have been previously presented on Tables 36 and 37.

Comparison of median level change between conditions

The median level for the comparison between intervention and maintenance for the numbers of appropriate marks made by S10 was +15. The median level for inappropriate marks for the same period was 0. There was no change in level stability for appropriate marks.or inappropriate marks. There was a 50% overlap between conditions for appropriate marks, and 66.6% overlap for inappropriate marks (see Table 36).

The median level of problems correct for the comparisons between intervention and maintenance was +3.5, and -3, for incorrect problems (see Table 37). There was no change in level stability for correct and incorrect problems. The percentage of data points that overlapped for correct problems was 50% and 100% for incorrect problems.

Comparison of trend changes using trend lines between conditions

A comparison of trends for appropriate marks between intervention and maintenance conditions resulted in a change in the direction of the trend line, from a sharp accelerating trend line to a slowly decaying trend line (see Figure 8). There was no change in trend stability between conditions for appropriate marks (see Table 36). No change in direction for the trend line was noted for inappropriate marks (see Figure 8). The trend line remained level.

A comparison of trends for problems solved correctly between intervention and maintenance conditions resulted in a change of trend direction from an accelerating trend line to a slowly decaying trend line (see Figure 8). No change in trend stability was noted (see Table 37).

For problems solved incorrectly, the comparisons made between intervention and maintenance conditions for trend direction resulted in no change of direction of the trend line (see Figure 8). There was no change in trend stability (see Table 37).

Summary of Overall Results for Question 2

During the maintenance phase of this experimental study, all subjects continued to exhibit appropriate written marks of the word problem solving strategy when attempting to solve word problems. Subjects use of appropriate marks for assistance in solving the word problems appeared to decelerate during the maintenance condition. Three of 10 students exhibited increasing instances of writing inappropriate marks during the maintenance condition. None of the subjects made more inappropriate marks than appropriate marks during the maintenance phase. Subjects demonstration of appropriate marks during the maintenance condition indicated that the subjects had retained the strategy once instruction in the procedure had ended.

The correct resolution of word problems continued for subjects in the maintenance condition. Subjects maintained correct problem solution levels higher than was exhibited during baseline conditions, and equal to or higher than correct problem solving levels observed during the intervention phase of the experiment.

The word problem solving strategy appeared to continued to be used by subjects in the maintenance phase. Successful problem solving attempts were continued to be obtained by subjects during the maintenance condition. It was hypothesized that a majority of the students would retain the problem solving strategy over time. This was shown by the data. It was also believed that as students became more proficient in using the strategy, the levels of inappropriate marks due to omissions would increase. The data also showed that this hypothesis to be valid.

Results for Individual Subjects Pertaining to the Generalization of a Mathematical Word Problem Solving Strategy to Multistep Word Problems

Subject 1

Subject 1 was under the generalization phase of the experimental study for 13 days. During this time period, Subject 1 was given generalization probes and practice in making her own word problems. On the first day of generalization, she was not instructed to use the strategy to solve the word problems. On the second day of generalization, she was instructed to use the strategy by her teacher. Subject 1 was given four lessons in making her own word problems. Finally on the fifth day, Subject 1 was shown how to use the strategy to solve multistep word problems.

The results of S1's generalization phase are presented on Table 38. The data are visually displayed on Figures 9 and 10.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S1 was 28. The median of inappropriate marks was 15 (see Table 38). Level stabilities for appropriate and inappropriate marks were variable. Range of appropriate marks was 23-49, and 3-43 for inappropriate marks.. An accelerating trend was observed for appropriate marks, and a decelerating trend was noted for inappropriate marks (see Figure 9).

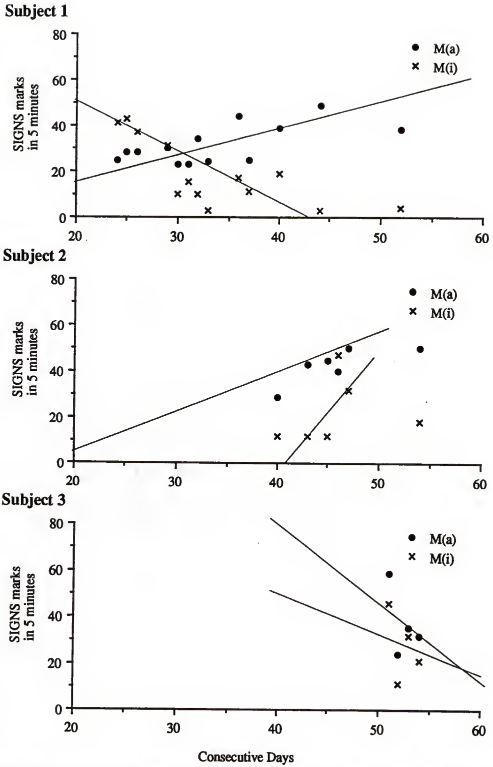


Figure 9 Number of appropriate (M(a)) and inappropriate (M(i)) marks made in 5 minutes by Subjects 1, 2, and 3 during generalization phase.

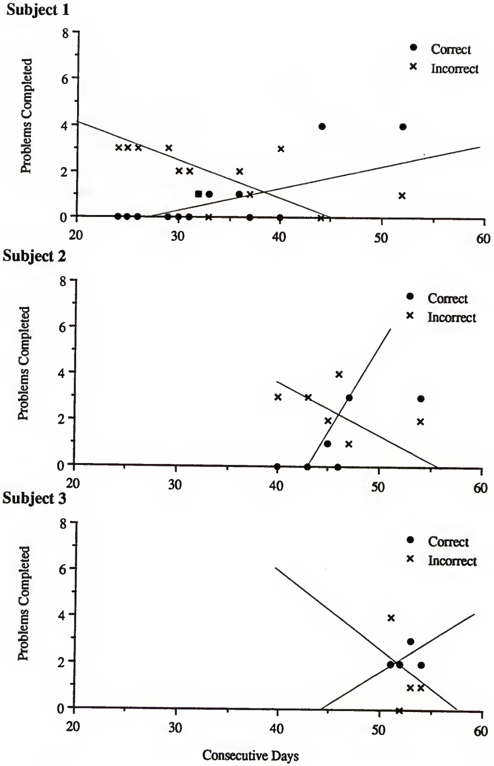


Figure10 Number of problems completed in 5 minutes by Subjects 1, 2, and 3 during generalization phase.

Table 38: Summary of Visual Analysis of Generalization Data Plotted in Figures 9 and 10 for Subject 1

	SIGNS Marks		Problems Solved	
Analysis	Appropriate	Inappropriate	Correct	Incorrect
Length in days	13	13	13	13
Median Level	28	15	0	2
Level Stability & Range	V (23-49)	V (3-43)	V (0-4)	V (0-3)
Trend Direction#	$(+)^8$	$(-)^9$	$(+)^7$	$(-)^7$
Trend Stability	V	V	V	V

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ; (-): Decelerating; (=): Level or no change; #: Number of data paths

The calculated median of problems correct for S1 was 0, with a range of 0-4 problems correct. The median for incorrect problems was 2 with a range of 0-3 problems incorrectly solved (see Table 38). An accelerating trend was noted for problems correctly solved, and a decelerating trend was noted for incorrectly solved problems (see Figure 10).

Subject 2

Subject 2 was under the generalization phase of the experimental study for 6 days. During this time period, Subject 2 was given generalization probes and practice in making his own word problems. On the first day of generalization, he was not instructed to use the strategy to solve the word problems. Following the first day of the generalization condition, he was given three lessons in the construction of word problems. On the third day, Subject 2 was able to correctly solve one of the multistep problems on the Generalization (G) probes.

The results of S2's generalization phase are presented on Table 39. The data are visually displayed on Figures 9 and 10.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S2 was 44. The median of inappropriate marks was 15 (see Table 39). Level stabilities for appropriate and inappropriate marks were variable. Range of appropriate marks was 29-50, and 12-47 for inappropriate marks.. An accelerating trend was observed for appropriate marks,

Table 39: Summary of Visual Analysis of Generalization Data Plotted in Figures 9 and 10 for Subject 2

	SIGNS Marks		Problems Solved	
Analysis	Appropriate	Inappropriate	Correct	Incorrect
Length in days	6	6	6	6
Median Level	44	15	0.5	2.5
Level Stability &	V	V	V	V
Range	(29-50)	(12-47)	(0-3)	(1-4)
Trend Direction#	$(+)^4$	$(+)^3$	$(-)^5$	$(+)^5$
Trend Stability	V	V	V	V

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ; (-): Decelerating; (=): Level or no change; #: Number of data paths

and an accelerating trend was noted for inappropriate marks (see Figure 9).

The calculated median of problems correct for S2 was 0.5, with a range of 0-3 problems correct. The median for incorrect problems was 2.5 with a range of 1-4 problems incorrectly solved (see Table 39). An accelerating trend was noted for problems correctly solved, and a decelerating trend was noted for incorrectly solved problems (see Figure 10).

Subject 3

Subject 3 was under the generalization phase of the experimental study for 4 days. During this time period, Subject 3 was only given generalization probes, no practice in making his own word problems was undertaken. On the first day of generalization, he was not instructed to use the strategy to solve the word problems. On the second day, Subject 3 was told to use the word problem solving strategy with the problems on the Generalization (G) probes. Subject 3 was able to correctly solve two of the multistep problems on the G probes.

The results of S3's generalization phase are presented on Table 40. The data are visually displayed on Figures 9 and 10.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S3 was 33.5. The median of inappropriate marks was 26.5 (see Table 40). Level stabilities for appropriate and inappropriate marks were variable.

Table 40: Summary of Visual Analysis of Generalization Data Plotted in Figures 9 and 10 for Subject 3

	SIGNS Marks		Problems Solved	
Analysis	Appropriate	Inappropriate	Correct	Incorrect
Length in days	4	4	4	4
Median Level	33.5	26.5	2	1
Level Stability &	V	V	V	V
Range	(24-59)	(11-46)	(2-3)	(0-4)
Trend Direction#	$(-)^3$	$(-)^3$	$(+)^3$	$(-)^3$
Trend Stability	V	V	V	V

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ;
(-): Decelerating; (=): Level or no change; #: Number of data paths

Range of appropriate marks was 24-59, and 11-46 for inappropriate marks.. A decelerating trend was observed for appropriate marks, and a decelerating trend was noted for inappropriate marks (see Figure 9).

The calculated median of problems correct for S3 was 2, with a range of 2-3 problems correct. The median for incorrect problems was 1 with a range of 0-4 problems incorrectly solved (see Table 40). An accelerating trend was noted for problems correctly solved, and a decelerating trend was noted for incorrectly solved problems (see Figure 10).

Subject 4

Subject 4 was under the generalization phase of the experimental study for 7 days. During this time period, Subject 4 was only given generalization probes . On the first day of generalization, he was not instructed to use the strategy to solve the word problems, Subject 4 was able to correctly solve one of the multistep problems on the Generalization (G) probes.

The results of S4's generalization phase are presented on Table 41. The data are visually displayed on Figures 11 and 12.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S4 was 30. The median of inappropriate marks was 1 (see Table 41). Level stabilities for appropriate and inappropriate marks were variable. Range of appropriate marks was 13-38, and 0-7 for inappropriate

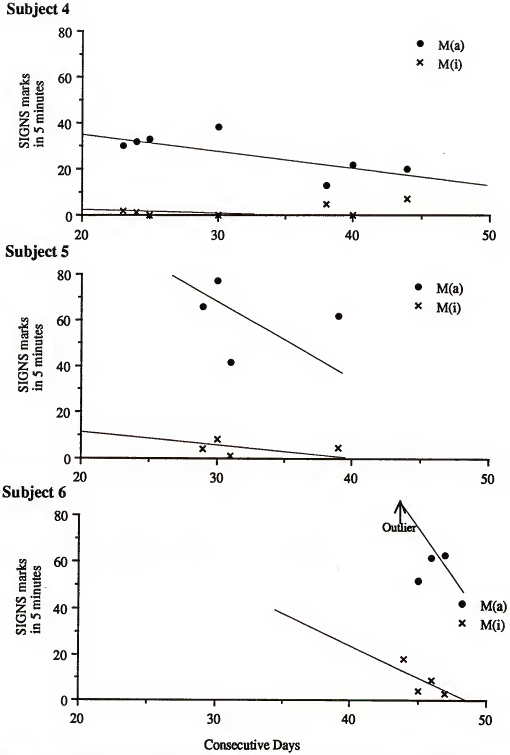


Figure 11 Number of appropriate (M(a)) and inappropriate (M(i)) marks made in 5 minutes by Subjects 4, 5, and 6 during generalization phase.

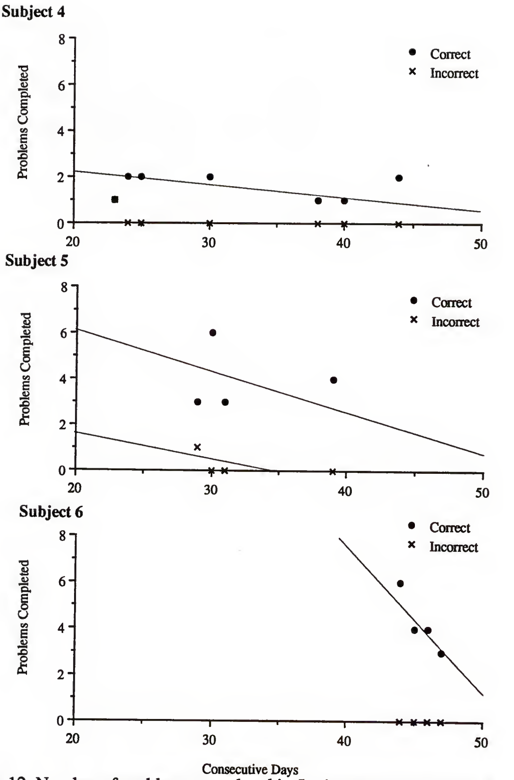


Figure 12 Number of problems completed in 5 minutes by Subjects 4, 5, and 6 during generalization phase.

Table 41: Summary of Visual Analysis of Generalization Data Plotted in Figures 11 and 12 for Subject 4

	SIGNS Marks		Problems Solved	
Analysis	Appropriate	Inappropriate	Correct	Incorrect
Length in days	7	7	7	7
Median Level	30	1	2	0
Level Stability &	V	V	V	S
Range	(13-38)	(0-7)	(1-2)	(0-1)
Trend Direction#	$(-)^4$	$(=)^4$	$(-)^4$	$(=)^2$
Trend Stability	V	V	V	V

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ;
(-): Decelerating; (=): Level or no change; #: Number of data paths

marks.. A decelerating trend was observed for appropriate marks, and a decelerating trend was noted for inappropriate marks (see Figure 11).

The calculated median of problems correct for S4 was 2, with a range of 1-2 problems correct. The median for incorrect problems was 0 with a range of 0-1 problems incorrectly solved.s (see Table 41). A decelerating trend was noted for problems correctly solved, and a level trend was noted for incorrectly solved problems (see Figure 12).

Subject 5

Subject 5 was under the generalization phase of the experimental study for 4 days. During this time period, Subject 5 was only given generalization probes. On the first day of generalization, he was not instructed to use the strategy to solve the word problems. On the first day during the generalization condition, Subject 5 was able to correctly solve three multistep problems on the Generalization (G) probes.

The results of S5's generalization phase are presented on Table 42. The data are visually displayed on Figures 11 and 12.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S5 was 64. The median of inappropriate marks was 4.5 (see Table 42). Level stabilities for appropriate and inappropriate marks were variable. Range of appropriate marks was 42-77, and 1-8 for inappropriate

Table 42: Summary of Visual Analysis of Generalization Data Plotted in Figures 11 and 12 for Subject 5

	SIGNS Marks		Problems Solved	
Analysis	Appropriate	Inappropriate	Correct	Incorrect
Length in days	4	4	4	4
Median Level	64	4.5	3.5	0
Level Stability &	V	V	V	V
Range	(42-77)	(1-8)	(3-6)	(0-1)
Trend Direction#	$(-)^3$	$(-)^3$	$(-)^4$	$(-)^2$
Trend Stability	V	V	V	V

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ;
(-): Decelerating; (=): Level or no change; #: Number of data paths

marks.. A decelerating trend was observed for appropriate marks, and a decelerating trend was noted for inappropriate marks (see Figure 11).

The calculated median of problems correct for S5 was 3.5, with a range of 3-6 problems correct. The median for incorrect problems was 0 with a range of 0-1 problems incorrectly solved (see Table 42). A decelerating trend was noted for problems correctly solved, and a decelerating trend was noted for incorrectly solved problems (see Figure 12).

Subject 6

Subject 6 was under the generalization phase of the experimental study for 4 days. Subject 6 was given generalization probes, no practice in making his own word problems was attempted. On the first day of generalization, he was not instructed to use the strategy to solve the word problems. He used the strategy and solved six problems correctly with no errors on the first day of the generalization phase.

The results of S6's generalization phase are presented on Table 43. The data are visually displayed on Figures 11 and 12.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S6 was 62.5. The median of inappropriate marks was 6.5 (see Table 43). Level stabilities for appropriate and inappropriate marks were variable. Range of appropriate marks was 52-115, and 3-18 for inappropriate

Table 43: Summary of Visual Analysis of Generalization Data Plotted in Figures 11 and 12 for Subject 6

	SIGNS Marks		Problems Solved	
Analysis	Appropriate	Inappropriate	Correct	Incorrect
Length in days	4	4	4	4
Median Level	62.5	6.5	4	0
Level Stability &	V	V	V	S
Range	(52-115)	(3-18)	(3-6)	(0-0)
Trend Direction#	(-)^3	(-)^4	(-)^3	(=)^1
Trend Stability	V	V	V	S

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ; (-): Decelerating; (=): Level or no change; #: Number of data paths

marks.. A decelerating trend was observed for appropriate marks, and a decelerating trend was noted for inappropriate marks (see Figure 11).

The calculated median of problems correct for S6 was 4, with a range of 3-6 problems correct. The median for incorrect problems was 0. Subject 6 made no errors on attempts at solving multistep word problems (see Table 43). A decelerating trend was noted for problems correctly solved, and a level trend was noted for incorrectly solved problems (see Figure 12).

Subject 7

Subject 7 was under the generalization phase of the experimental study for 8 days. During this time period, Subject 7 was given generalization probes. On the first day of generalization, he was not instructed to use the strategy to solve the word problems, no problems were correctly solved. On the second day, Subject 7 was able to correctly solve one of the multistep problems on the Generalization (G) probes.

The results of S7's generalization phase are presented on Table 44. The data are visually displayed on Figures 13 and 14.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S7 was 35. The median of inappropriate marks was 12 (see Table 44). Level stabilities for appropriate and inappropriate marks were variable. Range of appropriate marks was 21-45, and 1-39 for inappropriate

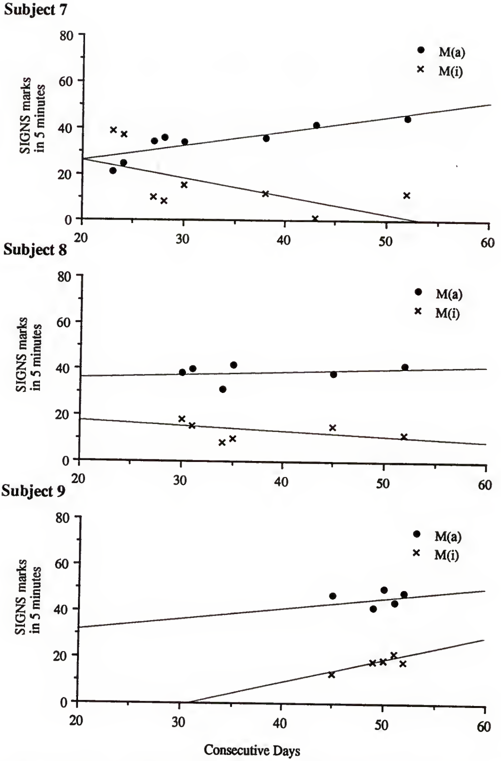


Figure 13 Number of appropriate (M(a)) and inappropriate (M(i)) marks made in 5 minutes by Subjects 7, 8, and 9 during generalization phase.

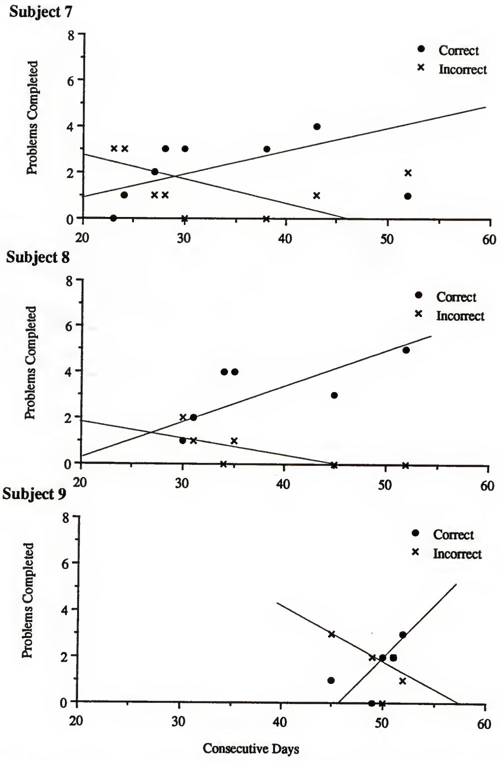


Figure 14 Number of problems completed in 5 minutes by Subjects 7, 8, and 9 during generalization phase.

Table 44: Summary of Visual Analysis of Generalization Data Plotted in Figures 13 and 14 for Subject 7

	SIGNS Marks		Problems Solved	
Analysis	Appropriate	Inappropriate	Correct	Incorrect
Length in days	8	8	8	8
Median Level	35	12	2.5	1
Level Stability &	V	V	V	V
Range	(21-45)	(1-39)	(0-4)	(0-3)
Trend Direction#	$(+)^3$	$(-)^4$	$(+)^4$	$(-)^4$
Trend Stability	V	V	V	V

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ; (-): Decelerating; (=): Level or no change; #: Number of data paths

marks.. An accelerating trend was observed for appropriate marks, and a decelerating trend was noted for inappropriate marks (see Figure 13).

The calculated median of problems correct for S7 was 2.5, with a range of 0-4 problems correct. The median for incorrect problems was 1 with a range of 0-3 problems incorrectly solved (see Table 44). An accelerating trend was noted for problems correctly solved, and a decelerating trend was noted for incorrectly solved problems (see Figure 14).

Subject 8

Subject 8 was under the generalization phase of the experimental study for 6 days. During this time period, Subject 8 was given generalization probes and practice in making his own word problems. On the first day of generalization, he was not instructed to use the strategy to solve the word problems. On the second day of the generalization condition, Subject 8 was able to correctly solve one of the multistep problems on the Generalization (G) probes.

The results of S8's generalization phase are presented on Table 45. The data are visually displayed on Figures 13 and 14.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S8 was 39. The median of inappropriate marks was 13.5 (see Table 45). Level stabilities for appropriate and inappropriate marks were variable. Range of appropriate marks was 31-42, and 8-18 for inappropriate

Table 45: Summary of Visual Analysis of Generalization Data Plotted in Figures 13 and 14 for Subject 8

Analysis	SIGNS Marks		Problems Solved	
	Appropriate	Inappropriate	Correct	Incorrect
Length in days	6	6	6	6
Median Level	39	13.5	3.5	0.5
Level Stability &	V	V	V	V
Range	(31-42)	(8-18)	(1-5)	(0-2)
Trend Direction#	(=)^4	(-)^3	(+)^3	(-)^3
Trend Stability	V	V	V	V

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ; (-): Decelerating; (=): Level or no change; #: Number of data paths

marks.. A slowly, accelerating trend was observed for appropriate marks, and a decelerating trend was noted for inappropriate marks (see Figure 13).

The calculated median of problems correct for S8 was 3.5, with a range of 1-5 problems correct. The median for incorrect problems was 0.5 with a range of 0-2 problems incorrectly solved (see Table 45). An accelerating trend was noted for problems correctly solved, and a decelerating trend was noted for incorrectly solved problems (see Figure 14).

Subject 9

Subject 9 was under the generalization phase of the experimental study for 5 days. During this time period, Subject 9 was given generalization probes. On the first day of generalization, he was not instructed to use the strategy to solve the word problems. Subject 9 was able to correctly solve one of the multistep problems on the Generalization (G) probes during the first day of the generalization condition.

The results of S9's generalization phase are presented on Table 46. The data are visually displayed on Figures 13 and 14.

Comparison of level and trend within the generalization condition

The median level of appropriate marks made by S9 was 47. The median of inappropriate marks was 18 (see Table 46). Level stabilities for appropriate and inappropriate marks were variable. Range of appropriate marks was 42-50, and 13-22 for inappropriate

Table 46: Summary of Visual Analysis of Generalization Data Plotted in Figures 13 and 14 for Subject 9

	SIGNS Marks		Problems Solved	
Analysis	Appropriate	Inappropriate	Correct	Incorrect
Length in days	5	5	5	5
Median Level	47	18	2	2
Level Stability &	V	V	V	V
Range	(42-50)	(13-22)	(0-3)	(0-3)
Trend Direction#	$(+)^4$	$(+)^2$	$(+)^3$	$(-)^3$
Trend Stability	V	V	V	V

Note. S: Stable; V: Variable; *: % of overlap; (+): Accelerating ; (-): Decelerating; (=): Level or no change; #: Number of data paths

marks.. An accelerating trend was observed for appropriate marks, and an accelerating trend was noted for inappropriate marks (see Figure 13).

The calculated median of problems correct for S9 was 2, with a range of 0-3 problems correct. The median for incorrect problems was 2 with a range of 0-3 problems incorrectly solved (see Table 46). An accelerating trend was noted for problems correctly solved, and a decelerating trend was noted for incorrectly solved problems (see Figure 14).

Subject 10

Subject 10 refused to participate in the generalization phase of the research study. No data were obtained.

Summary of Overall Results for Question 3

During the generalization phase of this experimental study, all subjects continued to exhibit appropriate written marks of the word problem solving strategy when attempting to solve word problems. Five of the nine subjects demonstrated positive rises in the exhibition of appropriate marks. The graphically displayed trend lines for two subjects showed negative increases in the exhibition of inappropriate marks during the same period. Three of the subjects made more inappropriate marks than appropriate marks across six sessions within the generalization phase. Subjects demonstration of appropriate marks during the generalization condition indicated that the subjects were able to apply the strategy steps to the solving of multistep word problems..

By the end of the generalization condition, all subjects were able to solve at least one multistep word problem correctly. Six of the nine subjects had positive, accelerating trend lines for the numbers of problems correctly solved and completed. The three subjects with decelerating trend lines exhibited higher levels of correct problem solving behavior than most of the subjects with rising trend lines.

Seven of the nine subjects exhibited positive, decelerating trend lines for the numbers of incorrect problems completed. The other two subjects exhibited flat, level trend lines with a median level of 0 incorrect problems.

The word problem solving strategy appeared to continued to be used by subjects in the generalization phase. Only one subject required assistance in learning to apply the word problem solving strategy to the solving of multistep word problems. One student experienced positive problem solving of multistep word problems after being exposed to activities designed to instruct individuals in making their own word problems. The majority of the subjects, 7 of 9, were able to use the strategy to solve multistep word problems without additional instruction or assistance. However, these students needed to be told to use the strategy when given the multistep word problems found on the generalization probes.

It was hypothesized that one-fourth to one-third of the students would generalize the strategy to solving of multistep mathematical word problems. The results showed that more than two-thirds of the students were able to generalize the strategy to multistep problems.

Summary

The results of this investigation showed subjects acquired the word problem solving strategy, SIGNS, when taught using an instructional procedure designed to promote acquisition and generalization. The results of this study also confirmed that by following the steps of the SIGNS strategy, subjects were able to increase correct mathematical word problem solving behavior. Results also showed subjects retained the strategy over a period of time and that subjects were also able to apply the strategy to the solving of multistep mathematical word problems. The strategy was shown to be an effective tool for assisting students in solving mathematical word problems.

CHAPTER V

DISCUSSION

Introduction

The findings and implications for the investigation of a word problem solving training procedure designed to provide middle and secondary school students with mild disabilities with a strategy for solving mathematical word problems are presented in this chapter. The chapter has been divided into five major sections. First, reviews of the purpose, literature, and methods are presented. Second, a summary and analysis of the results are also discussed. A discussion and implications of the research findings, as related to procedures for the delivery of instruction, procedures for teaching mathematical word problem solving, generalization, and other issues, are also presented. Fourth, limitations of the present research are also discussed. Finally, suggestions for future research are also presented.

Review of Purpose, Literature, and Methods

Review of purpose

Three purposes were germane to this investigation. The first purpose was to develop a mathematical problem solving strategy which included direct and mnemonic instruction. The second purpose was to evaluate the effectiveness of the instructional procedures on the acquisition and retention of the word problem strategy. The third purpose was to evaluate the subjects' ability to generalize the word problem strategy to the solving of multistep mathematical word problems.

Review of literature

Educators and researchers have voiced concern over the acquisition of functional mathematics skills by all children (NCSM, 1989), and the difficulties with mathematics experienced by students with mild disabilities (Cawley & Miller,1989; Deshler, Schumaker, Alley, Warner & Clark, 1982; Lee & Hudson, 1981). These concerns expressed the need for students with mild disabilities to acquire and develop essential mathematical skills and abilities. The NCSM (1989) stated that students need instruction that would allow students opportunities to demonstrate and apply problem-solving and higher order thinking skills to everyday life and unique situations.

Teaching approaches, methods and procedures including direct instruction (Carnine & Gersten, 1982; Darch, Carnine, & Gersten, 1984; Jones, Krouse, Feorene, & Saferstein, 1985; Gersten & Carnine, 1984; Wilson & Sindelar, in press), cognitive approaches (Huinker, 1989; Montague & Bos, 1986; Smith & Alley, 1981), and mnemonic instruction (Condus, Marshall, & Miller, 1986; Machida & Carlson, 1984; Mastropieri, Scruggs, & Levin, 1985; McLoone, Scruggs, Mastropieri, & Zucker, 1986; Scruggs & Mastropieri, 1989), have been empirically tested and have been found to be effective in teaching individuals to solve mathematical word problems, and in learning new information.

Research and development of effective teaching methods for assisting students to acquire, retain, and generalize information has been a goal of many in special education. Deshler and his associates (1981) found that a series of learning strategies interventions were successful in producing positive changes in LD adolescents' performances. These researchers have also developed and followed generalization procedures based upon techniques suggested by Stokes and Baer (1977) and have included them into a curriculum for assisting students with learning difficulties to succeed in the regular education environment (Lenz, Schumaker, Deshler, & Beals, 1984; Nagel, Schumaker, & Deshler,1986; Schumaker & Sheldon, 1985).

Mathematic educators have proposed that metacognitive techniques are needed to provide students with the essentials of problem solving skills and many have adopted Polya's four-step method for the teaching of problem solving. Polya (1957) stated that educators should teach students to (a) understand the problem, (b) devise a plan for solving the problem, (c) implement the plan, and (d) look back at the plan to determine whether the solution could have been obtained through alternate routes. Polya determined that the last step, looking back at the plan, was the most critical step of the problem solving process.

Garofalo and Lester (1985) elaborated on Polya's four-phase model for problem solving. They proposed that there are four categories of specific activities that are undertaken when solving mathematical problems: orientation, organization, execution, and verification, and each category required students to exhibit specific strategic behaviors.

Other researchers have examined the numerous variables that facilitate the solving of mathematical story problems. Variables examined included the selection of key words by problem solvers and the graphical representation of word problems as possible aids for solving mathematical word problems.

Researchers found that the presence of extraneous information in mathematical word problems created difficulties in problem solving performance for students with disabilities (Blankenship & Lovitt, 1976; Cawley, Miller & School, 1987; Cruickshank, 1948; Goodstein, Bessart, Thibodeau, Vitello, & Vlahakos,1972; Goodstein, Cawley, Gordon, & Helfgott,1971). Researchers also found that teaching students to cue into specific key words was not effective and should be discouraged (Cawley, Miller & School, 1987; Englert, Culatta, & Horn,1987; Nesher & Teubal, 1975. Researchers also found that visual and graphical representations of mathematical word problems assisted individuals with obtaining the correct solution to mathematical word problems (Bolduc, 1970; Lee, 1982; Neil, 1969; Portis, 1973;Threadgill-Sowder & Sowder, 1982; Yancey, Thompson, & Yancey, 1989).

Review of methods

Ten secondary-aged students with mild disabilities were included in this experiment. Four of the students were labeled as having emotional handicaps (EH) and were provided educational services in a special school. The other six students were labeled as having specific learning disabilities (SLD). Three of these students attended an urban, middle school and received educational services from various VE teachers. Three students attended a rural, combination junior-senior high school and received educational services from three VE teachers. All of the subjects were taught a strategy to assist them in solving mathematical word problems.

Nine of the students also participated in the generalization phase of the experiment. The tenth subject, an EH student, declined to participate in the generalization phase.

The independent variable in this experiment was a mathematical word problem solving strategy. The strategy combined direct instruction principles and the use of mnemonic instruction to teach students a process for solving word problems. The strategy was taught to the students through the use of scripted lessons and prepared practice worksheets. Once the skill was acquired by the subjects as demonstrated by an increase in appropriate marks and problems correctly solved, instruction was discontinued, and subjects moved to a maintenance phase and into the generalization condition.

The dependent variables in this experiment were the numbers of appropriate and inappropriate marks related to the strategy made by the subjects. A second set of dependent variables were the numbers of mathematical word problems correctly and incorrectly solved by the subjects. The dependent variables were measured through the use of a series of baseline, acquisition, and maintenance (BAM) probes and generalization (G) probes. The BAM probes contained 18 mathematical word problems equally divided across addition, subtraction, and multiplication operations. Six forms of BAM probes were administered to the subjects. G probes consisted of 18 multistep mathematical word problems. The 18 problems were equally divided across the following operations: (a) addition and subtraction, (b) addition and multiplication, and (c) subtraction and multiplication. For both sets of probes, problems involving division were not included. Both types of probes were administered for 5 minutes. The numbers of appropriate and inappropriate marks, and correct and incorrect problems were counted.

A multiple probe across subjects design was used to evaluate the effects of the instructional word problem solving strategy. The subjects were administered BAM probes across three conditions: baseline, intervention, and maintenance. The subjects were also administered G probes across one condition: generalization.

Summary and Analysis of Results

In this section the three research questions are reviewed and summarized. Interpretations of the results are also reported.

Question 1

To answer the first question regarding the acquisition of a word problem solving by students with mild disabilities, the effects of the intervention on the exhibition of appropriate marks and problems correctly solved were addressed. The findings indicated that the subjects were able to acquire the word problem solving strategy within acceptable limits of mastery.

Each of the ten subjects in this phase of the investigation demonstrated the ability to acquire the strategy as evidenced by increasing numbers of appropriate marks and problems solved correctly, and by the decreasing numbers of inappropriate marks and problems solved incorrectly. Nine of the ten subjects exhibited accelerating trend lines during the acquisition phase for the numbers of appropriate marks made. Eight of the ten subjects exhibited accelerating trend lines for the numbers of problems solved correctly during the same phase. Three of the subjects exhibited increased levels of appropriate marks made after the first instructional session. Six subjects increased the levels of appropriate marks made after the second instructional session. One subject's exhibition of appropriate marks increased after three days of instruction in the strategy.

The charted data for eight subjects showed accelerating trend lines for the numbers of problems solved correctly during the intervention phase of the study. Two other subjects trend lines were decelerating. Six of the ten subjects exhibited increased levels of the numbers of problems solved correctly after the second day of instruction. Two subjects exhibited increased levels of problems solved correctly after 4 days of instruction, while one subject each, exhibited increased correct problem solving levels after 1 day and 3 days of instruction respectively.

While the trend lines for some of the subjects decelerated during the intervention phase for the numbers of appropriate marks made, and the numbers of problems solved correctly, it was observed that the median levels for all of the students were higher during the intervention phase than during the baseline phases. The variability of the data obtained influenced the direction of the trend lines and resulted in the apparent appearance that the subjects had not acquired competence in the use of the strategy.

Question 2

To answer whether the subjects were able to retain the word problem strategy once instruction in the strategy had ended, the number of appropriate marks made and the number of problems correctly solved were examined. Within the maintenance conditions analyses were made for the median level for all ten subjects. All of the subjects exhibited increased median levels from acquisition to maintenance ranging from +1 to +39.5 for appropriate marks, and nine of the ten subjects showed increased median levels for the numbers of problems solved correctly ranging from +1 to +4. One subject exhibited no change in median levels between intervention and maintenance conditions.

Trend comparisons were made between intervention and maintenance conditions for five subjects. Trend comparisons were not done with five subjects due to the insufficient numbers of data points. Of the five comparisons made, three subjects exhibited changing trend lines from an accelerating direction to a decelerating direction for the numbers of appropriate marks made. One subject's trend lines changed directions from a decelerating line to a flat or level trend line. One subject's trend line maintained a positive, accelerating direction for the numbers of appropriate marks made. With regard to the numbers of problems correctly solved, two subjects trend lines maintained a positive, accelerating trend, while two other subjects trend lines changed from an accelerating direction during intervention to a level trend line. One subject exhibited a change during the same comparison conditions from an accelerating trend line to a decelerating directional trend line.

Overall, all of the subjects showed higher levels of appropriate marks made and problems solved correctly in relation to levels of inappropriate marks and incorrectly solved problems during the maintenance phase. The data clearly showed that the subjects were able to retain and use the word problem solving skills which was taught to them during the intervention phase. A visual inspection of the data provided the researcher to conclude that once the subjects learned the strategy, additional instruction in the application of the strategy was unnecessary.

Question 3

To answer whether the subjects were able to generalize the word problem strategy to multistep word problems, generalization probes were examined for numbers of appropriate and inappropriate marks made, and numbers of problems correctly and incorrectly solved. Trends and median levels were calculated for subjects within the generalization condition. Between conditions comparisons were not made as different assessment devices were used during the baseline, intervention and maintenance phases, and the generalization phase. The results are presented.

A total of nine subjects participated in the generalization phase of the study. One subject elected not to participate in the generalization phase, therefore no information was obtained for this subject.

During the generalization phase, all of the subjects demonstrated higher median levels of appropriate marks made than inappropriate marks made. Trend analysis of appropriate marks made by the subjects revealed that four of the subjects had accelerating, positive trend lines, four had decelerating, negative trend lines, and one individual had a flat, level trend line. Trend analysis of inappropriate marks made by the subjects also revealed that six subjects had positive, decelerating trend lines, two had negative, accelerating trend lines, and one individual had a flat, level trend line.

The analysis of the numbers of problems correctly and incorrectly solved revealed six of the nine subjects had higher median levels for the numbers of problems solved correctly when compared to numbers of incorrectly solved problems. It was found that two subjects had lower median levels, and one subject's median levels were not different between numbers of correctly and incorrectly solved problems. The range of the median levels of correct problems was 0 to 4 problems.

Trend analyses of the data revealed that five of the subjects exhibited positive, accelerating trend lines for problems solved correctly, while the remaining four subjects had negative, decelerating trend lines. For numbers of problems solved incorrectly, six of the nine subjects had positive, decelerating trend lines, one had a negative, accelerating trend line, and two subjects exhibited flat, level trend lines.

The data revealed that a majority of the subjects were able to generalize the word problem solving strategy to the solving of multistep mathematical word problems. A visual inspection of the charted data and the trend lines showed that while in some instances trend lines showed a negative direction, the accuracy levels of correct problem solved were higher towards the latter sessions of the study for most of the subjects.

Summary of the results

Overall, an analysis of the data suggests that students with mild disabilities were able to acquire, retain, and generalize a mathematical word problem solving strategy. The findings also lead the researcher to conclude that the use of a structured, organized, and sequential instructional plan, using direct instruction and mnemonic procedures, and empirically tested mathematical word problem solving techniques, appears to be an effective method for teaching students with mild disabilities to solve word problems involving addition, subtraction, and multiplication operations.

Implications

A discussion of the implications with regard to the procedures for delivering instruction,and for teaching mathematical word problem solving, generalization and other findings related to the study is presented. Implications for the classroom and research are also presented in the discussion.

Procedures for delivering instruction

The results of this study supported the effectiveness of the instructional procedures proposed by Deshler and his associates. Their instructional procedures, which combined the use of direct instruction procedures along with the use of mnemonics as aids for assisting students to remember skill sequences, were shown to be effective when applied to an instructional strategy for solving mathematical word problems. The systematic nature of the instructional procedures allowed the teacher and the student to feel confident that the student had learned the content and skill before progressing to new or more difficult skills and content.

The effectiveness of the instructional delivery system implemented in this investigation validated the teaching sequence proposed by Deshler and his associates. The sequential nature and logical progression of the instructional stages was tested and was noted to be beneficial for helping students learn new skills.

However, the instructional procedures proposed by Deshler and his associates were not able to provide instantaneous results once implemented. The present study showed that there may be a delay of 2-3 days before students are able to exhibit appropriate and desired behaviors related to the skills being taught. The observed delays in the demonstration of appropriate behaviors may be due to the individual student's learning characteristics.

Therefore, the classroom teacher must be aware that while the instructional procedures are directed towards a whole group approach for instruction, the ability to still implement individualized instruction and feedback should not be forgotten. The instructional procedures for teaching the strategy allows the teacher to be able to do both, conduct whole group instruction and conduct individualized instruction and corrective feedback. The instructional procedure allows the teacher the flexibility to ensure that the student has mastered the strategy.

Procedures for teaching mathematical word problem solving

The results of this study also allowed the investigator to determine that different components arranged in a sequential order for teaching mathematical word problem solving was effective. The preformulated plan for solving mathematical word problems contained elements which had been found to be effective by previous researchers. Requiring subjects to survey the problem by reading and underlining the numbers and number words focused the students' attention on reading the problem for specific details that were considered essential for the solving of word problems. By having the subjects identify the key words and labels that were contained within the problem, the strategy required the students to examine the details of the problem and to make logical choices of what they were being asked to find. Graphically representing the problem presented the subjects with an avenue in which they were able to discern what possible mathematical operations would be needed in order to solve the problem correctly. By requiring the subjects to write the equation or number sentence of what the drawing depicted served as a comprehension check for the subject's understanding of the word problem. By having the subject reread the question, they were required to determine if the drawing previously made, logically matched with what they were asked to find. Performing the solving and checking steps of the strategy on the word problem required the student to perform the mathematical calculations, check the calculations, and to write the appropriate label for what they were asked to find. Requiring the subjects to circle their complete answers provided the students with an avenue to show the teacher that they knew what the question asked them to find.

The findings also suggested that when used in combination with other methods, graphically displaying the problem and writing out the equation, the method of teaching students to look for key words and phrases may also have helped the students in solving word problems. Although Cawley and other researchers have emphatically stated that teaching students to look for key words is ineffective, the findings indicate that the key word method may be strengthened when used with other problems solving procedures.

The results of this investigation showed that by following a logical, structured sequence for solving mathematical word problems, students with mild disabilities were successful. The results also demonstrated the need for teachers to provide students with a strategy to provide students with an avenue that they are able to use when confronted with intimidating mathematical word problems.

Practitioners are advised not to abandon practices which have been proposed to be ineffective in isolated instances, but are advised to consider using these practices with other effective methods. The combination of methods may provide students with additional strategies which may be used to solve problems.

Generalization

The results of this investigation concluded that the SIGNS strategy which included a generalization phase to promote the strategy utilization by students in a variety of situations was effective in assisting students to generalize the strategy to multistep word problems. The generalization lessons of the SIGNS strategy were unique in that it presented the students with instruction on how to solve word problems by requiring them to form their own word problems. The instructions for assisting students to form their own problems were in a direct instruction format and presented opportunities for the students to practice applying the strategy. These lessons were only presented to a few of the students. A majority of the students generalized the strategy without being told to use it. Two of the students were told to use it and they did. A third student had to be shown how to implement the strategy to multistep word problems.

The findings may indicate that the students did not distinguish any difference in solving multistep word problems from simple, single-step word problems. The students may have also needed the assurance from the teacher that the strategy would still work with multistep word problems. The findings also suggest that for some students, a direct instruction approach is required for some individuals to apply the strategy to different types of mathematical word problems. The findings further suggest that students are able to generalize skills to new situations but may need some reassurances with regard to strategy use.

Other findings

An interesting phenomena also was found when the plotted data was examined. During the acquisition phase, all ten of the subjects exhibited crossover effects for appropriate marks made verses inappropriate marks made, and seven of the ten exhibited crossing over with regard to problems solved correctly. During the generalization phase, eight of the nine subjects exhibited similar crossover effects for appropriate marks and problems solved correctly. Once crossover occurred, subjects continued to maintain higher levels of appropriate marks made and correct problems solved than inappropriate marks made and incorrect problems solved. This crossing over effect was investigated by Sealander (1990) who found similar patterns. The presence of crossovers and the maintenance of positive behaviors indicates that once the subjects had acquired the strategy they did not appear to require further instruction in the strategy.

Another set of findings were obtained through an administration of social validation instruments to teachers and subjects at the culmination of the research study. The subjects were asked to respond to a forced choice questionnaire regarding learning of the strategy, solving of word problems before strategy instruction, and solving of word problems after they had learned the strategy. A majority of the subjects, seven of ten students, indicated that the strategy was easy to learn, use, and was helpful in solving word problems. Subjects also indicated that before learning the SIGNS strategy, they found word problems hard to do, disliked doing word problems, and in some cases, did not do word problems, and did not know where to begin when confronted with word problems. After learning the strategy, all of the subjects indicated that they knew what they needed to do to solve a word problem, were not afraid to try and solve word problems, found word problems not as hard as originally thought, and felt more confident about solving word problems. Three of the ten subjects indicated that they had used the word problem solving strategy to solve word problems found on quizzes, tests, and classroom assignments.

The three participating teachers were also asked to respond to an evaluative questionnaire. Teachers were asked to respond to an open-ended format questionnaire which consisted of seven questions. All three teachers indicated that the SIGNS Word Problem Solving strategy was not difficult to teach, but also indicated that instructing students in a group format would have made teaching the strategy easier. All of the teachers felt that the strategy was useful in assisting their students to solve word problems, and indicated that they would teach the strategy to other students who did not participate in the study. One teacher indicated that her students used the strategy to solve word problems on tests, quizzes, and classroom assignments. One teacher indicated that she would have preferred teaching the SIGNS strategy without the use of a prepared script. She indicated that teachers should be given the opportunity to generate their own teaching scripts which complement their style of teaching. The only difficulties noted by the teachers were related the characteristics of the students in their classrooms. One teacher stated she encountered difficulties due to the emotional and behavior problems which were present in her students. A second teacher indicated that student absenteeism and school-sponsored activities made it difficult to provide daily instruction in the strategy.

The evaluations provided by the students and teachers appear to support the premise that the word problem solving strategy is a useful procedure and should be taught to students who experience difficulties with the solving of mathematical word problems. The evaluations also indicated that teachers and students agree that the strategy is not a difficult strategy to teach or to learn. The comments provided by the teachers and students were an important aspect for the development and refinement of any new instructional procedure. The comments are necessary for the researcher to refine and improve upon the presentation materials, assessment materials, and other procedures that must be used when teaching the word problem solving strategy. Evaluative comments are important as they provide the researcher with invaluable information regarding the social validity of any procedure.

Limitations

Characteristics of the design, procedures, and subjects used in this study limit the extrapolation and interpretation of results. The use of the multiple probe design affected the number of data points that were obtained from subjects during baseline phases. No conclusions should be made regarding the effectiveness of the intervention with word problems requiring the solving of problems involving division. The problems which the subjects were required to solve, and received practice on were limited to addition, subtraction and multiplication of whole numbers. Extrapolation to other mathematical operations involving fractions, decimals, and irrational numbers, as well as higher more abstract mathematical operations (i.e. algebra, geometry, and trigonometry) is unwarranted. The number of subjects, the grade range, disabling condition, and ability levels, while appropriate for the implemented experimental design, was limited. Caution should be exercised when generalizing these results to other, similar students.

Suggestions for Future Research

There are numerous suggestions for future research which may be undertaken. Four suggestions are presented. The first involves the investigation of the comparing the effectiveness of the word problem solving strategy with current procedures implemented in public schools for teaching mathematical word problem solving. A large group comparison investigation is suggested in order to gauge the effectiveness of the strategy between comparable groups of individuals. Differences in acquisition, retention, and generalization information would be compared.

A second suggestion for future research is to compare the effectiveness of the strategy with younger, elementary school-aged children educated in regular education and special education settings. In this proposed research investigation, information may be obtained on the differences between the two groups on the length of time needed for students to acquire the strategy, the differences strategy retention, and differences on children's' abilities to apply the strategy to unique, novel, and more complex mathematical word problems.

A third suggested investigation for research would involve an examination of the instructional delivery system. Comparisons between groups of students in which teachers followed prepared scripts and those groups in which teachers are not provided a script may be conducted using acquisition, retention, and generalization information. The investigation may provide valuable information with regard to the effectiveness of teacher training verses teaching materials for instructing students to solve mathematical word problems.

In as much as reading comprehension, and language competency appear to serve as two prerequisites for the solving of mathematical word problems, an investigation of the acquisition, retention, and generalization of the mathematical word problem solving strategy with limited English proficient (LEP) and non-English language background (NELB) individuals is also suggested. An investigation examining the instructional procedures and the specific steps of the word problem solving strategy on mathematical word problems by LEP and NELB individuals may provide educators with additional instructional methods to assist these students.

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APPENDIX A
SIGNS INSTRUCTIONAL PROCEDURES AND MATERIALS

TEACHING SCRIPT FOR INSTRUCTION

SIGNS Word Problem-Solving Strategy

[Begin Lesson 1 after student has taken the third 5 minute probe. Day 4 of study.]

[1st day of instruction]

Lesson One:	Obtaining student commitment and describing the SIGNS word problem-solving strategy
Materials:	Cue Cards 1, 2, 3, 4, 5, 6, & 7, pencil, paper, BAM probe

Advance Organizer

"Have you been having trouble solving the word problems?" [Wait for student response.] **"Yes, it is hard to solve word problems, many people I know have had a hard time solving word problems. When I was in school, many of my classmates didn't like it when the teacher gave us some word problems to solve in math class. Many of us had a very difficult time. We had a hard time deciding where to start and what to do. Would you like to learn how to solve word problems?** [Wait for answer, if student answers "Yes", continue; if student answers "no", ask student why he/she does not want to learn how to solve word problems. Point out to student that he/she is having difficulty in solving word problems and ask the question again. When student says "yes" continue by saying,] **"Great!! I would like to teach you a strategy for solving word problems. What is a strategy?"** [Wait for answer, if no response, say,] **"A strategy is a plan or set of steps to get a goal."** [Now ask,] **"What is a strategy?"** [Now wait for response and then say], **"For a strategy to be effective, you must want to learn and use the strategy. Are you**

ready to learn the strategy? ..[Wait for response.] **"Good, The name of the strategy is SIGNS. Before I start teaching you the SIGNS strategy, I need to have you write down your commitment to learn this strategy. Do you know what it means to make a commitment?"** [Wait for response, if student is unsure about what "commitment" means, explain that it means that the student promises to learn and practice the strategy. Have the student write a commitment on a piece of paper, date it and sign it. An example would be: "I want to learn and practice the SIGNS strategy." Student signs and dates the paper. Collect the papers and say,] **"Great, you have committed yourself to learning and practicing a strategy that will help you solve word problems. Now, let's begin!! First, I will describe the strategy."**

Describe: **"The name of the strategy is called SIGNS because it will show you the way to solve word problems. What is the name of the strategy?** [Wait for response.] **" Yes, the name of the strategy is SIGNS."** [Show Cue Card 1.] **"The 'S' in SIGNS stands for Survey the question. What does the 'S' stand for?"** [Wait for response.] **"Good, the S stands for Survey the question.** [Show Cue Card 2.] **"When you survey the question, you read the question, and underline the numbers and number words. What do you do when you survey the question?"** [Wait for response.] **"Yes, you read the question, and underline the numbers and number words."**

[Show Cue Card 1.] **"The 'I' in SIGNS stands for Identify the key words and labels. What does the 'I' stand for?** [Wait for response.] **"That's right, it stands for Identify the key words and labels.** [Show Cue Card 3.] **"When you identify the key words and labels, you draw 2 lines under the key words and labels. What do you do when you** identify the key words and labels ? [Wait for response.] "Yes, you draw 2 lines under the key words and labels. What are key words and labels? [Wait for response. Show Cue Card 4.] "Key words are words and phrases that give you clues to how to solve the problem. They tell you what you need to find. What do key words do? [Wait for response.] "Yes, key words give you clues to how to solve the problem and tell you what you need to find. Labels tell you the names of the objects that will be a part of the answer. For example, 4 birds, 9 helicopters, 14 boxes of cookies. Labels hep you to remember what you need to find. What do labels tell you? [Wait for response.] Correct, labels help you to remember what you need to find."

[Show Cue Card 1.]"The 'G' in SIGNS stands for Graphically draw the problem. What does 'G' stand for? [Wait for response.] "Right, the 'G' stands for graphically draw the problem." [Show Cue Card 5.] "When you graphically draw the problem, read the problem, and draw a picture that shows what the problem asks you to find. What do you do when you graphically draw the problem?" [Wait for response.] "Yes, you draw a picture that shows what the problems asks you to find."

[Show Cue Card 1.] "The next step in the SIGNS strategy is Note the operation needed to solve the problem. The 'N' stands for this step. What does the 'N' stand for? [Wait for response.] "Good, it stands for note the operation needed to solve the problem. [Show Cue Card 6.] "When you note the operation needed, look at the drawing and decide if the picture tells you to add, subtract, or multiply, and then you write the problem out. For example, 4 + 3 = ? 16 - 9 = ? 7 X 5 = ? What do you do when you note the operation? [Wait for response.] "Yes, you look at the problem, decide if you add, subtract, or multiply, and then write the problem out. When you read the problem and it may give you a clue that there are groups, and in each group there are objects. When groups and objects in each group are given, you will need to find a total. So for multiplication, remember G (for groups) times O (for objects) equals T (for total). GO=T. Remember GOT for multiplication."

[Show Cue Card 1.] "The last step in the SIGNS strategy is Solve and check. What does the last 'S' in SIGNS stand for? [Wait for response.] Right, the last 'S' stands for solve and check. [Show Cue Card 7.] When you solve and check, compute the answer, check your addition, subtraction, and multiplication, write the label with the answer, and circle your complete answer. What do you do when you solve and check? [Wait for response.] Yes, when you solve and check the problem, you compute the answer, check your work, write the correct label with the answer, and circle the complete answer."

"Now you know what the SIGNS strategy is, and how you can use it to solve word problems Tomorrow you will continue to learn more about the SIGNS strategy."

[Give student BAM Probe Sheet]. [Set timer for 5 minutes.] "You have 5 minutes to solve as many word problems as you can. Please begin . [Turn timer on. At the end of time, collect probe sheets.]

[2nd day of instruction]

Lesson Two: Modeling the SIGNS word problem-solving strategy

Materials: Cue Cards 8, 9, & 10, pencil, paper, BAM probe

Advance Organizer: **"Yesterday, the word problem-solving strategy SIGNS was described for you. What does S stand for?** [Wait for response, if correct say **"Yes, you're right!"** if response is incorrect, say **"S stands for survey the question."** Then ask, **"What does I stand for,..what does G stand for,..what does N stand for, ..What does S stand for?"** [Wait for response for each question, praise or correct if necessary.]

Instruction: **"I'm going to demonstrate how to use the SIGNS strategy . I'm going to read aloud and tell you everything I'm thinking about as I use the strategy, so you can understand how I expect you to talk to yourself as you use this strategy. I will show you how to use it with some examples."** [Pass out Cue Cards 8, 9, & 10]. **"I will be using these cue card sheets to demonstrate the use of the strategy. Before I begin, do you have any questions before I begin?** [Answer any questions]

"Let's see, the first thing I do when I need to solve a word problem is to use SIGNS. S stands for survey the question. Hmmm...I need to read the question and underline the numbers and number words." [Read the question and start underlining the numbers.] **"Let's see, 7 is a number, so I'd better underline it. 4 is a number so I'll underline it also. 2 is a number. Better underline it too. No more numbers to underline. Now, the next step in SIGNS is to identify the key words and labels. When I find the key words and labels I make 2 lines under the**

words. Hmm...marbles appears to be a key word or a label, so I'd better underline the word marbles. [Underline marbles.] **What else..oh, I know, the question is asking How many marbles does he have left? How many and left tell me what I need to find, so I'd better underline them also. They must be key words.** [Underline How many and left.] **"The next step of SIGNS is the G step. G means to graphically draw out the problem. I need to read the problem again and draw a picture the tell me what I need to find.** [Draw the picture on Cue Card 8 for teacher] and say **"Let's see..I better draw 7 marbles. and 4 are red so, I'll make them look different. Now Tom gave 2 marbles to Bill so I need to show that 2 marbles were given away. I'll circle the 2 marbles that were given away and I'll draw an arrow to show that the marbles were being given away. Great, now I have a drawing that shows what I need to find. The next thing I need to do is to note the operation that best describes what the drawing shows. Hmm...so I'll read the problem again and I'll look at the drawing. Hmm...the drawing shows a subtraction problem so I will write the equation 7-2=. Yes, the drawing is definitely a subtraction problem. Now I need to do the last step of SIGNS. I need to solve and check my problem. Let's see,...7 minus 2 is 5. I can check my answer to see if it is correct by adding the 2 and 5. If the answer is 7, I am right!** [Do check. Add 2 + 5 and get 7.] **Yes, I'm right! Now I need to write the label with my answer so that the teacher will know that I know what the problem was asking me to find. Let's see, the correct label would be marbles. So I'll write marbles next to my answer.** [Write marbles next to 5.] **So my answer is 5 marbles, but to be sure that the teacher knows that 5 marbles is my answer, I need**

to circle my answer. [Circle the answer.] **Great, I've done it. The teacher will know that 5 marbles is my answer for this problem."**

"Did you see how I used the strategy to solve this word problem? I would like to do another one. Would you please help me do it? Great. [Give Cue Card 9] **"Let's see, what is the first thing I need to do?** [Wait for response and continue using the strategy until you come to G step.]

"Great, now the next thing I need to do is to ? [Wait for response.] **Yes, I need to graphically draw the picture. Let's see I need to draw 6 baskets.** [Draw 6 baskets.] **Now in each basket I need to put in 4 eggs.** [Draw in 4 eggs in each basket.] **Now that I have drawn my picture I need to write the equation that the picture is describing. Hmm..this problem looks like a GOT problem. Groups times Objects equals Total. So I need to write the equation. How many groups do I have?** [Wait for response.] **How many objects in each group?** [Wait for response.] **Good, so my equation is** [write 4 X 6 =]. **4 time 6 equals...**[Continue modeling rest of the problem with assistance from student. You may then continue with the next problem, Cue Card 10 if you feel student needs more practice. If student does not need practice. Say **"Great, you now know how to use the strategy. Tomorrow we will continue learning more of the strategy."** Give BAM Probe Sheet. 5 minute time limit. Collect sheet.]

[3rd day of instruction]

Lesson Three: Verbal Rehearsal of the SIGNS word problem-solving strategy

Materials: Cue Cards 1-8 pencil, paper, BAM probe

"Today you are going to memorize the steps of the Word Problem-Solving Strategy. If you know the steps and what you need to do for each step well, then you will be able to tell yourself what to do when you try to use the strategy when having to solve word problems. To help you memorize the strategy steps, we are going to do an exercise called rapid-fire verbal practice. We will also do an exercise know as verbal elaboration. I will be asking you to name the steps of the strategy in order, and what you need to do for each step. Sometimes I will just say a letter of the strategy. You will then tell me what the letter stands for and what you must do when you use it for solving word problems. Tell me the step and what you need to do as quickly as you can. If you need to look at your cue cards, you may; however, don't rely on the cue cards too much because, at one point I will tell you to put them away. To help you remember the strategy, rely on the mnemonic "SIGNS" and your own memory.

"This is what I want you to say if what does the 1st S stand for? You say, "Survey the question. You need to read the question and underline the numbers and number words. Then I will ask the next letter, in order until you can say them in order. Then I will ask the letters out of sequence, for example G,..1st S,..I,....last S,..N..etc......

Let's see how fast we can go to memorize these steps.

[Now take out verbal rehearsal checklist and test student to see how well student knows each of the steps. Make a √ if the student is able to say the step and tell what needs to be done for each step. Provide student with corrective feedback if he/she is making errors in naming the strategy steps Test the student daily until he/she is able to say all steps correctly with 100% accuracy for 3 consecutive days.]

"Great you are making great progress in learning the strategy. We'll continue this until you can say it with no mistakes. We will continue with this tomorrow." [Give student BAM Probe with 5 minute time limit. Collect probe sheet.]

[start of 4th day of instruction continues until student gets 80% accuracy on controlled practice sheets.]

Lesson Four:	Verbal rehearsal and controlled practice with the SIGNS word problem-solving strategy
Materials:	Cue Cards 1-8, pencil, paper, Controlled Practice Sheets, BAM probe

"Today we will continue with our verbal rehearsal. [Do verbal practice of SIGNS steps and stages for about 5 minutes. Test student. Then give Controlled Practice Sheets Set 1 to student. Say, **"Great you are learning the strategy, now here are some problems that you can use to practice the strategy with. When you are done, raise your hand and I will look them over.** [give student Controlled practice sheet to work on. When student is done, go over worksheet with student, point out correct and incorrect portions of the worksheet. Give positive feedback and have student practice saying the steps that they may have had trouble with and what they need to do. Student stays in this stage for at least 3 days. I will let you know if he needs to be moved to the next set of advanced practice materials.]

"Great, now you will have 5 minutes to do these sheets." Give student BAM probe and collect after 5 minutes.

Maintenance Procedure

After student has achieved mastery using SIGNS to solve one-step word problems with 70% accuracy for 3 days, discontinue instruction and give BAM probes for 3 days to assess retention of strategy. On the same 3 days, give student G Probe 1, on first day, G Probe 2 on second day, and G Probe 3 on third day. Give student

5 minutes to work on the G Probe sheets. After 3 days, if student has not demonstrated mastery in solving the 2-step word problems on G Probe sheets, implement generalization procedures.

Generalization Teaching Script

[1st day of generalization instruction.]
Lesson1:

"You have invested a lot of time in learning the Word Problem Solving strategy. You know how to solve word problems. That's great!! Many times, you will need to solve more difficult word problems in math class. Other times, you will need to solve math word problems for science, social studies, or vocational classes. Sometimes you will need to use problem solving skills when shopping for items for special occasions, like birthdays, holidays, or parties or for buying things from mail order catalogs or classified advertisements. Many of these problems may seem difficult to do but, if you know how to make your own problems, you may be able to solve some of these more difficult problems."

"Today you will be making your own problems. You will also be solving these problems using SIGNS. Are you ready? [Wait for response.] **Great!! Let's begin!"**

"I'm going to make my own problems and then I'll use SIGNS to solve it. By using SIGNS to solve it, I will know that my problem makes sense. What will I be doing? [Wait for response.] **Yes, I'll be making my own problems and using SIGNS to solve it. Why do I use SIGNS on the problem that I just made?** [Wait for response.] **Right!! I'll use SIGNS to make sure that my problem makes sense.**

[Show Cue Card 11.] **Look at Cue Card 11. Cue Card 11 shows a word problem with some information missing. Above the problem, there are some words and numbers. The words and numbers will be used for filling in the blanks of the problems.** [Point to the numbers and words.] and say, **Show me the information that will be used to fill in the blanks.** [Wait for response.] **Good, the numbers and words will be used to fill in the blanks of the word problem. There is are 2 blanks next to answer.** [Point to blanks next to Answer: on Cue Card.] **I will write the complete answer for my word problem here. Where do I write the complete answer for the word problem?** [Wait for response.] **Yes, I write the complete answer in the 2 blanks next to Answer. Now let's get started.** [Read problem out loud.] **"Robby had blank blank . In each blank he will put blank blank. The blank were for his mother and sisters. How many blank does Robby need for the blank ? Let's see, I need to look at numbers and words that will be used to fill in the blanks. I can choose to use 4 baskets, 3 cookies,or 12 cookies for each of the blanks that need 2 words or numbers. I can choose to use cookies or baskets to fill in the blank for the sentence "The blank were for his mother and sister." and for "How many blank does Robby need for the blank ?" Let's see. Hmmm. Let me read the problem again. Robby had blank blank . Hmm. I can use 4 baskets, 3 cookies or 12 cookies. I don't know which one to use. I'd better read on. In each blank he will put blank blank. Let's see. It says that Robby put something in each blank. Robby probably wouldn't put a basket in each cookie but he could put cookies in a basket. So I will fill in the blank in "In each blank " with the word "basket". Now,it reads, "In each basket he will put blank blank."**

Each means that he will have some baskets and he will put some cookies in each basket. This looks like a multiplication problem so I will find a number that is the product of 2 numbers that have been given. Which number is the product of the other 2 numbers? [Wait for response.] Yes, 12 is the product of 3 times 4. I see that the 12 is written with cookies. I can write 12 cookies in my answer blanks. Now I have to fill up the other blanks in the problem. Looking at my list of choices, I see that I can use 4 baskets or 3 cookies to fill in some of my blanks. Let's see. "Robby had blank blank." What could I write in those blanks? [Wait for response.] What could I write in those spaces? [Wait for response.] Yes, I could write 4 baskets. Now for the next set of blanks, if I used 4 baskets I must use 3 cookies. Now let's read the question again. "Robby had 4 baskets. In each basket he will put 3 cookies." Up to this point, does the question make sense? [Wait for response.] Yes, it does, doesn't it. Now lets fill in the rest of the blanks. Looking at our words, I can use, cookies or baskets to fill in the rest of the blanks. What word can I put in the next sentence? [Wait for response.] Yes, I can use either cookies or baskets. Both words would make the sentence meaningful. [Accept either "The baskets were for his mother and sisters. or The cookies were for his mother and sisters." Now the last sentence. "How many blank did Robby need for the blank ?" What words should I put in the blanks to make the whole question make sense? [Wait for response.] Yes, I will write cookies in the first blank and baskets in the second blank. Now let's read the completed problem. "Robby had 4 baskets. In each basket he will put 3 cookies. The baskets (or cookies) were for his mother and sisters. How many cookies did Robby need

for the baskets? " I also have written 12 cookies as the complete answer. Now I need to use SIGNS to see if I can solve the problem. What are the steps in SIGNS that I need to do? [Wait for response.] **Yes, you are correct, now I will use SIGNS to solve my problem.** [Implement SIGNS procedures and solve problem. Proceed with second problem on Cue Card 11 in similar fashion. Get students involved with procedure. Once problem is solved, say **"Look at the first problem. Now look at the second problem. Do you see any similarities in the problems?** [Wait for response.]. **Yes, both problems have used 12 cookies. In the first problem, 12 cookies is the answer. In the second problem, 12 cookies is used in calculating the answer for the second problem. Sometimes 2 problems are related and you need to use information from 1 problem to solve another problem.**

Now you will be given some practice in making your own problems. Follow the same steps that I did when I made my own problems. You will decide what numbers and labels need to used to fill in the blanks. You will also use SIGNS to check your problem to make sure that your problem makes sense. Are you ready? [Wait for response.] **What will you be doing?** [Wait for response.] **Yes, you will be making your own problems and you will check to see that your problems make sense by using the SIGNS strategy.** [Give student Practice Sheet G-1. After student has completed the practice sheet. Give student corrective feedback. Now give student G Probe 4 sheet. Student will be given 5 minutes to do the probe sheet. At the end of 5 minutes, collect G Probe 4 sheet. Cue Card 12 has been provided if you feel that the student needs additional practice for this activity. Follow the same procedures as you did with Cue Card 11.

If student has demonstrated 80% correct performance on G Probe 4 sheet discontinue generalization instruction. Continue to give student G Probes and 1 sheet for 3 consecutive days following administration of G Probe 4.

If student has not demonstrated 80% correct performance on G Probe 4 sheet continue with second day of generalization training.

Lesson 2:

"Yesterday, you learned how to begin making your own word problems. You did really well. Today you will continue to make your own problems. [Show Cue Card 13]. **Look at this problem. It has 4 numbers above the word problem.** [Point to the numbers above the problem.] **What are the numbers?** [Wait for response.] **Yes, the numbers are 7, 8, 15 and 22. We will be using 3 of these numbers for our word problem. Now look at the word problem. How many blanks are there?** [Wait for response.] **Yes, there are 6 blanks. If we are only using 3 numbers, what are the other 3 blanks for?** [Wait for response.] **Yes, the other 3 blanks are for the labels that we will use in the word problem. Now let's begin, first I need to read the problem , blanks and all.** [Begin reading.] **Blank blank were swimming at the lake. Blank more blank came to swim at the lake. How many blank went swimming? Hmm..before I start filling in the blanks with numbers, I need to think of a label that I can use in some of the blanks that would make sense. What labels could I use?** [Wait for response.] **Yes, I could use** [student response], **or girls, or boys, children, or ducks. I think that I will use the word students. I will write in the word "students" in the blanks that are provided for the labels. I know that the labels usually follows a number, and that the label is usually**

what is asked to find in the question part of the word problem. [Point to the 1st blank and say.] **Should I write "students" in this blank?** [Wait for response.] **You're right, I shouldn't write the label "students" before the number.** [Point to the 2nd blank.] **Should I write "students" in this blank?** [Wait for response.] **Yes, I can write "students" in this blank because it follows a blank that will probably contain a number.** {Go to 3rd blank.] **Should I write "students" in this blank?** [Wait for response.] **I really shouldn't because the sentence wouldn't make any sense if it read "Students more blank came to swim." What should I write in this blank?** [Wait for response.] **Yes, a number should be written in this blank but I'm not writing in numbers yet.** [Point to 4th blank.] **Would it make any sense if I wrote "students" in this blank?** [Wait for response.] **Yes, it would make sense, so I will write "students" in this blank.** [Write "students" in the blank.] **For this last blank, what should I write in it?** [Wait for response.] **Yes, you're right, I should write the word "students" in the blank.** [Write "students" in the blank.] **Now let's look at the answer blanks. What should I write in the first blank?** [Wait for response.] **Yes, I will need to write a number in this blank. What about for the second blank for the answer?** [Wait for response.] **Yes, I should also write the word "students" here. Why do I need to write "students" as part of the answer?** [Wait for response.] **Correct!! The word "students" is the label for the answer. It tells me what I will need to find. Now, I need to look at the numbers given above the problem. What are the numbers?** [Wait for response.] **Right! The numbers are 8, 7, 15, and 24. Hmm..By looking at my problem, I can see that I need to fill in 3 empty blanks with 3 of the 4 numbers. What numbers do I need to use**

to make this problem make sense? Let's see, when I read the problem, the key word "more" tells me that I will need to add a certain number of students who went swimming to the first group of students who went swimming. Let's see if I add 8 plus 7, the answer is 15. Is 15 one of the numbers given? [Wait for response.] You're correct, 15 is one of the numbers written above the problem. Let's continue to see if any of the numbers above the problem are the sums of 2 of the numbers given. If I add 7 plus 5, what is the answer? [Wait for response.] Yes, the answer is 12. Is 12 one of the numbers above the problem? [Wait for response.] Correct, 12 is not one of the numbers given. If I add 8 plus 15, the answer is? [Wait for response.] Yes, the answer is 23, but 23 is not one of the numbers given. What about 7 plus 15? [Wait for response.] Good, 7 plus 15 is 22. 22 is not one of the numbers that is given. If I add 15 plus 24, what is the sum? [Wait for response.] Is 39 a possible answer? [Wait for response.] Great! 39 could not be a possible answer, because it has not been written as a possible number for one of the answer blanks. Hmm...Let's think now. What number would be a good number to be a part of the answer? [Point to the 1 st blank in the answer section. Wait for response.] Yes, 15 would be a good number because of all of the possible addition combinations we tried, only 15 is a number we got that is a sum of 2 of the numbers written above the problem. Now, I can write 15 on one of the blanks. Where should I write the number 15? [Wait for response.] Great. I should write the 15 in the answer blank before the label "students" in the answer section. Of the numbers provided, what numbers, when added together make 15? [Wait for response.] Yes, 7 and 8 when added together make

15. Now we can write 8 in one of the remaining blanks and 7 in the other blank. Now I need to check to see if the problem makes sense. To do this, I will need to read the problem. Please read the problem with me. [Read problem out loud with student.] **Great! Now I need to solve the problem I just made. What strategy should I use when I solve this problem?** [Wait for response.] **That's right!! SIGNS.** [Continue with the second problem in a similar manner. After the second problem has been done. Point out that the answer from the first problem "15 students" was used in finding the answer for problem 2, either 6 or 9.]

[Give student Practice Sheet G-1, After student has completed the practice sheet. Give student corrective feedback. Now give student G Probe 1 sheet. Student will be given 5 minutes to do the probe sheet. At the end of 5 minutes, collect G Probe 1 sheet.

If student has demonstrated 80% correct performance on G Probe 1 sheet discontinue generalization instruction. Continue to give student G Probes for 3 consecutive days following administration of G Probe 1.

If student has not demonstrated 80% correct performance on G Probe 1 sheet continue with third day of generalization training.

CUE CARD 1

Step 1 : Survey the question

Step 2: Identify the key words and labels

Step 3: Graphically draw the problem

Step 4: Note the type of operation(s) needed

Step 5: Solve and check the problem

CUE CARD 2

Survey the Question

Read and

Underline the

Numerals and/or number words

CUE CARD 3

Identify the key words and labels

1) Find the key words and labels

2) Draw 2 lines under key words and labels

CUE CARD 4

Identify the key words and labels

- Key words are usually verbs that tell what is happening in the problem.
- Key words and labels tell you what you will need to find.

CUE CARD 5

Graphically draw the problem

1) Read the problem again

2) Draw a picture that describes what the problem asks you to find.

CUE CARD 6

Note the operations needed

1) Read the problem again

2) Look at the drawing

3) Write the equation that best describes the drawing

CUE CARD 7

Solve and check the problem

1) Compute the answer

2) Check your calculation

3) Write the label with the answer

4) Circle the complete answer

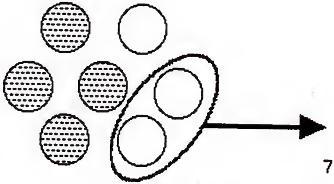
CUE CARD 8

Tom had 7 marbles. 4 marbles were red. He gave 2 marbles to Bill. How many marbles does he have left?

CUE CARD 8

(teachers's Cue Card 8)

Tom had 7 marbles. 4 marbles were red. He gave 2 marbles to Bill. How many marbles does he have left?



$7-2 = \boxed{\text{5 marbles}}$

$$\begin{array}{r} 7 \\ -2 \\ \hline 5 \end{array} \qquad \begin{array}{r} 5 \\ +2 \\ \hline 7 \end{array} \ \checkmark$$

CUE CARD 9

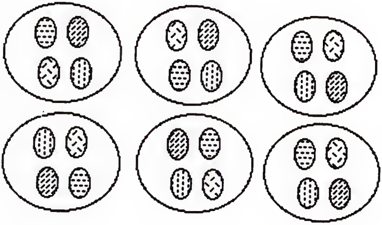
Carol had 6 baskets. She wanted to put 4 eggs in each basket. The baskets were brown. She needed to buy the eggs. How many eggs would Carol need to buy?

CUE CARD 9

(teachers's Cue Card 9)

Carol had 6 baskets. She wanted to put 4 eggs in each basket. The baskets were brown. She needed to buy the eggs. How many eggs would Carol need to buy?

GE=T



= 4 X 6 = 24 eggs

$$\begin{array}{r} 6 \\ +6 \\ +6 \\ +6 \\ \hline 24 \end{array}$$

✓

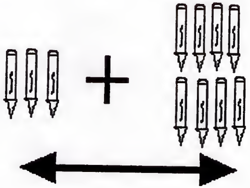
CUE CARD 10

Carl had 3 pencils. His mother gave him 8 more pencils. Carl needed 4 pencils for school. How many pencils does Carl have?

CUE CARD 10

(teachers's Cue Card 10)

Carl had 3 pencils. His mother gave him 8 more pencils. Carl needed 4 pencils for school. How many pencils does Carl have?



= 3 + 8 = 11 pencils

$$\begin{array}{r} 3 \\ +\,8 \\ \hline 11 \end{array} \quad ✓$$

CUE CARD 11

4 baskets 3 cookies 12 cookies

1. Robby had ___ _______ . In each basket he put ___ _______ . The baskets were for his mother and sister. How many cookies did Robby need for the baskets?

Answer: ___ ______

Solve the problem:

12 cookies 3 cookies 9 cookies

2. Robby bought ___ _______ and 3 muffins. His dad was hungry and ate ___ ______ . How many more cookies will Robby need to buy?

Answer: ___ ______

Solve the problem:

CUE CARD 12

3 pineapples   7 oranges   10 pieces of fruit

1. For a cooking class, Susan and her friends were making a fruit salad. They bought ___ ____ and ___ _____ . How many pieces of fruit did they buy?

Answer: ___ _____

Solve the problem:

14 pieces of fruit   6 pieces of fruit 10 pieces of fruit

2. Susan bought ___ _____ . Of the fruit, ___ _____ were not ripe enough for the fruit salad. How many pieces of fruit could she use for the salad?

Answer: ___ _____

Solve the problem:

CUE CARD 13

8 7 15 24

1. ___ ______ were swimming at the lake. ___ more _____ came to swim at the lake. How many ____ went swimming?

Answer: ___ ______

Solve the problem:

15 9 6 3

2. Of the ___ _______, _____ were members of the swimming team. How many _____ were members of the swimming team?

Answer: ___ ______

Solve the problem:

CUE CARD 19

Generalization Steps

Step 1: Orientation

Step 2: Activation

Step 3: Maintenance

Name: ________________________

WORD PROBLEM-SOLVING VERBAL PRACTICE CHECKLIST

	Attempts				
Naming Strategy Steps and Components	1	2	3	4	5
Survey the question					
Read and underline	----	----	----	----	----
numbers/number words.	----	----	----	----	----
Identify the key words and labels					
Draw 2 lines under key	----	----	----	----	----
words and labels	----	----	----	----	----
Graphically draw the problem					
Draw the problem	----	----	----	----	----
	----	----	----	----	----
Note the type of operation needed					
Write the equation	----	----	----	----	----
	----	----	----	----	----
Solve and check the problem					
Compute the answer	----	----	----	----	----
Check your calculation	----	----	----	----	----
Write the label with the	----	----	----	----	----
answer	----	----	----	----	----
Circle the complete answer	----	----	----	----	----

APPENDIX B
INSTITUTIONAL REVIEW BOARD

UNIVERSITY OF FLORIDA
INSTITUTIONAL REVIEW BOARD
114 PSYCHOLOGY BUILDING
GAINESVILLE, FL 32611-2065
(904) - 392 - 0433

April 17, 1991

TO: Mr. Addison K. Watanabe
G315 NRN

FROM: C. Michael Levy, Chair,
University of Florida Institutional
Review Board

SUBJECT: Approval of Project #91.103
The effects of a mathematical word problem solving strategy on problem solving performance by middle school students ...

I am pleased to advise you that the University of Florida Institutional Review Board has recommended the approval of this project. The Board concluded that your subjects will not be placed at risk in this research, and it is essential that you obtain legally effective informed consent from each participant's parent or legal guardian. When it is feasible, you should obtain signatures from both parents.

If you wish to make any changes in this protocol, you must disclose your plans before you implement them so that the Board can assess their impact on your project. In addition, you must report to the Board any unexpected complications arising from the project which affect your subjects.

If you have not completed this project by April 17, 1992, please telephone our office (392-0433) and we will tell you how to obtain a renewal.

By a copy of this memorandum, your Chair is reminded of the importance of being fully informed about the status of all projects involving human subjects in your department, and for reviewing these projects as often as necessary to insure that each project is being conducted in the manner approved by this memorandum.

CML/her

cc: Vice President for Research
College Dean
P. Sindelar
Dr. Cecil D. Mercer

Unfunded

APPENDIX C
COUNTY SCHOOL BOARD

APPLICATION FOR RESEARCH IN ALACHUA COUNTY SCHOOLS

Applicant:Addison Watanabe Phone:392-0755 Date:3/20/91

Address: G315 Norman Hall, U of Fl., Gainesville, FL. 32611

Applicant is: Doctoral Student

Title of Research Proposal: The effects of a mathematical word problem solving strategy on problem solving performance by middle school students with mild disabilities.

Purpose of Research: This is an investigation to show that students with mild disabilities are able to acquire, retain and generalize a problem solving strategy.

Brief Summary of Proposal: This investigation will teach students a strategy for solving single step mathematical word problems through the use of scripted lessons and prepared worksheets.

Population Needs: 3-4 Subjects. Middle school students with mild disabilities who have difficulties solving mathematical word problems.

Data Needed: IQ test scores, if available, and any other standardized tests of achievement.

Total Time Required: 6 to 8 weeks, daily for 20 to 30 minutes.

School Requested: A.Quinn Jones School.

If this application is approved, I agree to observe all legal requirements regarding the use of research and submit a final copy of the research report to the Alachua County School Board.

APPLICATION FOR RESEARCH IN ALACHUA COUNTY SCHOOLS

Applicant: Addison Watanabe Phone: 392-0755 Date: 3/20/91

Address: G315 Norman Hall, U of Fl., Gainesville, FL, 32611

Applicant is: Doctoral Student

Title of Research Proposal: The effects of a mathematical word problem solving strategy on problem solving performance by middle school students with mild disabilities.

Purpose of Research: This is an investigation to show that students with mild disabilities are able to acquire, retain and generalize a problem solving strategy.

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Population Needs: 3-4 Subjects. Middle school students with mild disabilities who have difficulties solving mathematical word problems.

Data Needed: IQ test scores, if available, and any other standardized tests of achievement.

Total Time Required: 6 to 8 weeks, daily for 20 to 30 minutes.

School Requested: Westwood Middle School.

If this application is approved, I agree to observe all legal requirements regarding the use of research and submit a final copy of the research report to the Alachua County School Board.

APPLICATION FOR RESEARCH IN ALACHUA COUNTY SCHOOLS

Applicant:Addison Watanabe Phone:392-0755 Date:3/20/91

Address: G315 Norman Hall, U of Fl., Gainesville, FL. 32611

Applicant is: Doctoral Student

Title of Research Proposal: The effects of a mathematical word problem solving strategy on problem solving performance by middle school students with mild disabilities.

Purpose of Research: This is an investigation to show that students with mild disabilities are able to acquire, retain and generalize a problem solving strategy.

Brief Summary of Proposal: This investigation will teach students a strategy for solving single step mathematical word problems through the use of scripted lessons and prepared worksheets.

Population Needs: 3-4 Subjects. Middle school students with mild disabilities who have difficulties solving mathematical word problems.

Data Needed: IQ test scores, if available, and any other standardized tests of achievement.

Total Time Required: 6 to 8 weeks, daily for 20 to 30 minutes.

School Requested: Hawthorne Junior-Senior High School.

If this application is approved, I agree to observe all legal requirements regarding the use of research and submit a final copy of the research report to the Alachua County School Board.

APPENDIX D
PARENT PERMISSION

Dear Parents:

I am conducting an investigation in the area of math problem solving. I will be investigating the effects of a math word problem solving strategy on problem solving performance by middle school students with mild disabilities. The purpose of this investigation is to determine whether the solving of word problems is improved by following a set of steps. It is hoped that the information gained from this investigation will provide a simple and effective method to help individuals solve word problems.

Specifically, I am asking for your permission to include your child in this investigation, as well as your permission to obtain ability, math and reading achievement information concerning your child from school records. All students, whose parents provide permission, will be asked to complete a worksheet containing basic addition, subtraction and multiplication facts, and a worksheet containing word problems involving addition, subtraction, and multiplication. This will take approximately 10 to 15 minutes. Based on measures of problem solving performance, students will be selected to learn the word problem solving strategy. Students will be given instruction in the strategy for 20 to 30 minutes and will take place for approximately 5 to 6 weeks.

The results of this investigation will be used to judge the effectiveness of the math problems solving strategy. While the results will be reported, your child's name will not appear and will remain anonymous. Also, being included in the investigation will not affect your child's math grade. If for any reason you wish, of you child wishes, to withdraw from the investigation at any time, it may be done without question.

If you have any questions about any part of this investigation, please call or write Addison Watanabe, G-315 Norman Hall, University of Florida, Gainesville, FL. 32611, Phone 392-0701 (work) or 378-9064 (home).

As a safeguard to your child and in order to comply with the procedures of the Alachua County School Board and the University of Florida, you permission is requested. Please have your child bring this slip back to school tomorrow. Thank you for your cooperation.

Sincerely,

Addison Watanabe

---------------------------(Cut here and return bottom)----------------------------------

Please check the appropriate box and return this portion of the sheet with your child tomorrow.

_____ I give my permission for my child, _______________, to participate in this investigation with the understanding that it is intended to help the solving of word problems.

_____ I do not give my persmission for my child, ___________, to participate in this investigation and receive addtional instruction.

_____ I am interested and would like to know more about this investigation. Please call me at _______________.

Parent/Guardian Date

Parent/Guardian Date

APPENDIX E
CHILD ASSENT

Child Assent Script

Researcher will say:

I would like to teach you a method for helping you solve word problems that are found in your math textbooks. You will not be punished if you do not participate. Your grade for this class will not be affected. If you choose to participate, you will not be forced to do anything that you do not want to do. At anytime during the lessons, you can choose to not continue to participate. You can quit at anytime. Do you understand? (Wait for response.) Good, remember, you can change your mind and not participate. Would you like to participate? (Wait for response.)

APPENDIX F
SAMPLE BASELINE, ACQUISITION, AND MAINTENANCE, AND GENERALIZATION PROBES

BAM Probe 1

Name:______________________________ Date:__________

Solve the following problems. You will have 5 minutes.

1. Mrs. Harris has 7 pencils. 2 pencils are red. She gave Mike 3 pencils. How many pencils does she have left?

2. Cecil collected 6 cans of peaches, 4 cans of pears and 3 cans of beans. Ann gave Cecil 2 cans of pineapple. How many cans of fruit did Cecil collect?

3. Bill is having a party. Altogether 7 people will be at his party. He wants to give each person 4 cookies. He will buy chocolate chip and oatmeal cookies. How many cookies does Bill need to buy?

4. Sara walked to the park. She saw 4 boys playing basketball, 2 girls jumping rope, and 4 girls reading on a bench. The boys were from her class at school. How many people were playing?

5. Mrs. Crocker's 7th grade math class was going on a field trip. 7 parents said that they would drive their cars for the field trip. Each parent said that they could have 5 students ride with them. How many students can ride with the parents?

6. Don bought 18 pencils. He gave 3 red pencils to Sam, 4 green pencils to John, 2 yellow pencils to Julie, 4 red pencils to Susan, and kept the rest for himself. How many pencils did he give to his girl friends?

7. Yesterday, Paul, Bob, and Stuart went to the video arcade. Each boy played 8 games on their favorite video game. They also bought popcorn at the video arcade. How many total games were played by the boys?

8. While at the mall, Stephen and Mary stopped at the bookstore. Mary bought a cooking book and 2 computer magazines. Stephen bought 2 books on birds. He also bought 2 magazines on hiking and fishing. Stephen loves to hike. How many magazines did Stephen and Mary buy?

9. While at the store, Cary bought 7 packages of pens. Each package had 4 pens. He bought 2 package of blue pens, 1 package of red pens, and the rest of the packages had black pens. Altogether, how many pens did Cary buy?

10. Susan received 6 boxes of playing cards. Each box contained 9 decks of playing cards. The cards were for a card party that she was having. How many decks of cards did Susan get for her party?

11. 6 girls and 4 boys from Mrs. Green's class went to the cafeteria for a special teat. 9 girls and 8 boys from Mr. Jones' class went to the cafeteria also. The students were going to eat pizza. How many girls went to the cafeteria for the special treat?

12. My father was going to paint some of the rooms in our house. He said that he needed 3 gallons of blue paint and 2 gallons of white paint for the bedrooms. My mother said that my father should also buy 4 more gallons of white paint for the living room. My mother found 3 gallons of blue paint in the garage and said that my father only had to buy white paint. How many gallons of paint does my father need to buy?

13. Charlie and Cathy found 9 boxes of colored chalk and 3 boxes of white chalk. Each box had 8 pieces of chalk. How many pieces of colored chalk did they find?

14. Yesterday, the pet store had 18 snakes for sale. Today, after school, I went to the pet store and counted 11 snakes. The clerk said that a woman had come early this morning and bought snakes. The clerk said that no other snakes were sold. How many snakes were sold by the clerk to the woman?

15. The afterschool basketball league was forming teams. Each team could have 8 players. The league only had 8 coaches so only 8 teams could be formed. I will play on a team. How many total people can play for the afterschool basketball league?

16. Cindy and Sharon are good friends. Cindy gave Sharon some candy. Cindy had 8 pieces of candy and how she has 5 pieces left. She did not eat any candy. How many pieces did Cindy give Sharon?

17. 18 boys and 17 girls were eating lunch. 9 of the boys and 6 girls were asked to go to Mrs. Brown's room. All of these students were needed for the school play. Of the students eating lunch, how many were needed for the school play?

18. Mr. Smith has a restaurant. The restaurant has 8 tables and 10 booths. Each table can seat 6 people and each booth can seat 4 people. Today at lunchtime, all of the booths are filled but all of the tables are empty. How many more people can find seats in his restaurant?

BAM Probe 3

Name:______________________________ Date:__________

Solve the following problems. You will have 5 minutes.

1. If a week has 7 days, and it took Lisa 3 weeks to save money for a new jacket, how many days in all does she need to save her money?

2. I had a party at my house last Saturday night. 13 people were invited but only 6 people came. How many people did not come to my party?

3. The zoo had 9 elephants. 7 more elephants were given to the zoo. 3 of the elephants were babies. How many elephants are there now?

4. 9 basketball players each played in 8 games. As a group, what was the total number of basketball games did the players play?

5. Fred needed to fill-up his fuel tank for his truck and his car. He put 9 gallons of gas into the truck and 7 gallons of gas into the car. The truck and car were made small for parades. How much gas did Fred have to buy?

6. Tim was told to take 2 pills, 4 times a day. Tim has a cold. How many pills did Tim take in 1 day?

7. Mom made 17 cupcakes for the bake sale. She made 8 chocolate cupcakes and 9 yellow cupcakes. My brothers Fred and Dan ate 6 cupcakes. How many cupcakes are there now for the bake sale?

8. It took Jane 9 hours to travel from Orlando, Florida to Atlanta, Georgia. Then it took her 8 more hours to get to Nashville, Tennessee. Jane loves to drive. Altogether how many hours did it take her to travel from Orlando to Nashville?

9. Donna gave me 16 comic books. I gave my brother 8 of those comic books. How many comic books did I keep for myself?

10. 8 airline employees needed earplugs. Each person had to wear 2 earplugs. How many earplugs must be ordered by the airline company?

11. A fishing boat caught 9 sharks a year for 3 years. What was the total number of sharks caught by the fishing boat for those years?

12. Daniel worked an average of 7 hours a week as a lifeguard during the 8 weeks of his summer vacation. What was the total number of hours Daniel worked as a lifeguard?

13. Albert has to sell 13 tickets for the school play by Wednesday. The school play is called "Ten Little Indians". He has already sold 5 tickets. How many more tickets does he have to sell by Wednesday?

14. Tony drove his car 6 miles on Monday and 9 miles on Tuesday. On Wednesday, Tony had a flat tire. How many miles in all did he drive?

15. There were 10 goldfish in Mr. McGregor's fish pond. Yesterday he found 4 goldfish floating dead in the water. How many goldfish does Mr. McGregor have left in the fish pond?

16. On Wednesday, 9 new students showed up for football tryouts. The next day, 8 more new students came out for tryouts. The coach wants a winning team. In all, how many students tried out for the football team?

17. 15 cars began a race across the United States. 8 cars finished the race. The car from New Mexico won the race. How many cars did not finish the race?

18. The space shuttle orbited Earth for 7 days last year, and 9 days this year. The shuttle costs a lot of money. How many days did the space shuttle orbit during both years?

G Probe 1

Name:______________________________ Date:__________

Solve the following problems. You will have 5 minutes.

1. Charly loves to chew erasers. His mother gave him 3 erasers on Monday, 2 erasers on Wednesday, and 1 eraser on Friday. Charly chewed up 4 of the erasers. Charly also chewed up 2 pens. How many good erasers does he have left?

2. John had 4 bags of red marbles with 3 marbles in each bag. He also has 2 bags of blue marbles with 2 marbles in each bag. He also has 1 empty bag with no marbles. How many marbles does John have altogether?

3. For each of 5 days, 6 geese landed on our pond and stayed. On the 6th day, 4 geese flew away. How many geese were left?

4. Glenda put 3 M&M's on each of the 3 small cookies, and 5 M&M's each on the 2 large cookies. Glenda baked 4 pies also. How many M&M's did Glenda use?

5. 18 students began a reading contest. Before finishing the first book, 9 students left. The remaining students each read 4 books. How many books were read by the students that stayed in the contest?

6. Jaime has 6 pairs of yellow socks, but 2 pairs were dirty. She also had 5 pairs of white socks. All of her white socks were clean. How many pairs of clean socks does she have?

7. The local baker put 2 trays of bread dough into the oven to bake. Each tray holds 8 loaves. When the baker removed the trays of bread, he had to throw away 4 loaves. The bread had burned. How many loaves of bread was he able to package for sale?

8. Temple Junior High School had 3 prize packages of 2 movie tickets each for the 3 top spellers in their annual school spelling bee. Then Mr. Madden decided the first place winner should have 4 more movie tickets for winning the spelling bee. What was the total number of movie tickets the school provided for the annual spelling bee?

9. My father was putting in new windows. Friday he put in 5 windows but 1 fell out and broke. Saturday he put in 4 more new windows. How many windows did my father put in?

10. If 7 people ate 6 pieces of pizza each, and another person ate 7 pieces of pizza. How many pieces of pizza in all were eaten by these people?

11. In the aquarium I have 7 guppies and 4 neon tetras. 3 guppies had 9 babies each; but, when the babies were removed only 20 were found. How many baby guppies were missing?

12. Leslie babysat for the Smith family 9 evening this month and for the Fox family 8 evenings this month. Leslie is earning money to buy some new clothes. This month has 28 evenings. How many evenings did Leslie not babysit for other families?

13. Ronald is a runner. He loves to run in races. This week he ran 6 miles a day for 6 days to prepare for an important race. The actual race course was 8 miles long. Including the actual length of the race course, how many miles did Ronald run this week?

14. Paul ordered some t-shirts. The store said that it cost 5 dollars each for shirt. He bought 9 t-shirts for his family. 3 of the shirts were white and 6 were blue. Because he paid cash, the store subtracted 4 dollars from his bill. How much did Paul pay for the shirts?

15. Patty has a stuffed animal collection. She decided to give away some of them to her little sister, Tammy. She had 10 stuffed bears, 8 stuffed lions, and 6 stuffed elephants. She gave Tammy 4 bears, 2 lions and 3 elephants. Tammy loves elephants and had 16 stuffed elephants. How many stuffed animals are now in Patty's collection?

16. For 9 days straight, the city of Winston had 2 inches of rain during the month of February. For the rest of the month, the city received 9 more inches of rain. What was the total amount of rainfall, the city of Winston received for February?

17. Our basketball team scored a total of 9 points in each of 4 quarters. Our basketball team has not yet won a game. But the referee said that the last 3 points made by Frank could not be counted as Frank shot the ball after the buzzer sounded. How many points did our team officially score at the end of the game?

18. 7 cars began the race with 3 passengers and 1 driver. The race was a 700 miles long. Before the race ended, 20 passengers left their cars. They were too tired. All of the cars finished the race. How many people finished the race?

G Probe 2

Name:____________________________

Date:__________

Solve the following problems. You will have 5 minutes.

1. John earned $ 18.00 this week by helping his neighbor. He had to pay back his brother $3.00 and $6.00 to his sister for money that they had loaned him. How much money does John have left to spend?

2. Dan,of Dan's Golden Used Car Lot, had set a goal for his salepeople. He wanted each of his salespersons to sell at least 7 cars during the Sale-O-Rama. Dan has 8 salespeople. His salespeople met their goal. One person sold 3 cars over the goal of 7 cars. How many cars were sold during Dan's Sale-O-Rama?

3. My neighbor and I had 7 recycling containers filled with newspaper. Each container had 9 pounds of newspapers. We took the containers to the recycling center. When we got to the recycling center, we found that we had forgotten 2 recycling containers. How many pounds of newspaper did we end up leaving at the recycling center?

4. Ruby's flower shop delivered 7 bouquets with 6 flowers in each bouquet on Valentine's Day. On the same day, the flower shop also delivered a vase with 3 long stem roses to the owner of a bookstore. How many flowers did Ruby's flower shop use in all?

5. Before putting out the table decorations Mary decided to take out the yellow flowers. Each table decoration had 16 flowers. Of the 16 flowers, 9 were red, the rest were yellow.. Mary had ordered 8 table decorations. How many yellow flowers did Mary remove from the table decorations?

6. Jimmy takes karate lessons. He usually takes 3 karate lessons in a week. He has been taking karate lessons for 8 weeks. Next week Jimmy will only be able to go to karate for 2 lessons. By the end of next week, how many karate lessons will Jimmy have taken?

7. Jeff had 9 CD's that he brought to Harriet's party. Each CD had a total of 9 songs. Harriet was glad to get the music but her parents said that she would not be able to play 2 of the CD's at her party. How many songs will Harriet be able to use from the CD's that Jeff brought?

8. A local horse stable ordered 2 bags of feed to be delivered to them each week for 8 for each horse that it has. The stable has currently 5 horses. Next week, the stable will be getting 4 more horses. How much feed will the stable need to order next week?

9. Two trucks delivered crates of vegetables and crates of fruit. One truck delivered 8 crates of vegetables and 9 crates of fruit. The other truck delivered 4 crates of vegetables and 7 crates of fruit. What was the difference in the amount of crates of vegetables and fruits delivered between the two trucks?

10. At the school picnic, 5 people each won 6 games. Daniel won 8 games. Including Daniel, how many games were won at the picnic?

11. 13 students went to the fair. 4 of the students wanted to buy popcorn, the others wanted to buy peanuts. The popcorn cost $1.50 and the peanuts cost $2.00. How much money was spent on peanuts?

12. In the Jumpstart Race, the athletes had to bicycle for 9 miles and run 8 miles. Alvin finished the cycling portion of the race but had to drop out 2 miles from the finish line because he fell and hurt his ankle. How many miles did Alvin complete?

13. In one football game, Garrett caught 5 short passes averaging 5 yards each. He also ran with the ball 3 times. For each time he ran with the ball, Garrett averaged 5 yards. What was the total yardage gained by Garrett?

14. Grandma grew some tomato plants from seeds. She had 9 tomato seedlings in a tray. She had 8 trays. Yesterday she gave 3 trays to her neighbors. How many tomato seedlings does Grandma have left?

15. Dave collects football trading cards. Yesterday he was given 8 cards and today he bought 6 more cards. He found that he already had 5 of the cards so he gave them tohis brother. How many cards did he keep for himself?

16. James was a pitcher for a baseball team. In his best game, he struck out an average of 2 players per inning for 8 innings, and in the last inning, he struck out all 3 batters. What was the total number of stikeouts James threw during his best game?

17. For the Fall Festival parade, the firemen bought 9 cases of candy to give to children along the parade route. Each case had 8 boxes of candy. When the parade started, 3 cases of candy were forgotten by the firemen. How many boxes of candy would the firemen be able to give to the children?

18. Susan made 6 apple pies and 8 cherry pies for the bake sale. She sold 4 apple pies and 5 cherry pies. How many pies were not sold?

APPENDIX G
INTERSCORER INSTRUCTIONS AND FORM

Scoring the Probes

For each problem on a probe sheet, use the following steps.

Step 1: Count all numbers or number words underlined once. Record frequency of responses in "A" box under S on Interscorer Sheet.

Step 2: Count all number/number words not underlined or incorrectly underlined (double underlined, etc..). Record the total number of incorrectly underlined or missed numbers under "I" box under the S.

Step 3: Count all labels and key words that have been underlined with 2 lines. If the question has been underlined, count it as 1 instance of underlining. Labels are words that tells what objects are being added, subtracted or multiplied. Labels are words that cue the problem solver what needs to be found. Key words include words that give the problem solver clues and assistance in solving the problem. Verbs are considered key words as they provide the problem solver with information about what is happening in the problem. Words such as "each", "all together', "how many", etc...are also key words. Count the total number of labels and key words underlined and record in "A" box under I.

Step 4: Count all key words and labels not underlined correctly or not underlined. Record the number of incorrect responses in "I" box under I.

Step 5: If a correct graphical representation is provided by the problem solver for the problem, record a 1 in the "A" box under G. If there is no drawing, or if the drawing is incorrect, record a 1 in the "I" box under G. Record a 1 in either box, one box must be 1 and the other box must be 0.

Step 6: If a correct mathematical equation is written down for the problem (i.e., 2 + 2 =, 5 X 9 =, 12 - 8 =,..), record a 1 in the "A" box under N. If the equation is missing, or is incorrect, record a 1 in the "I" box under N. Record a 1 in either box, one box must be 1 and the other box must be 0.

Step 7: Give 1 point each if the solver has:

a) Calculated the problem correctly;
b) Checked the answer;
c) Written the label with the answer; and
d) Circled the complete answer (number and label).

The maximum total that may be given under the 2nd S boxes is 4 points. For each of the 4 parts, give the solver either a 1 or a 0.

Follow the procedures for each problem attempted by the problem solver.

Subject: __________ Probe #: __________ Date: __________

Prob. #	S		I		G		N		S		Total	
	A	I	A	I	A	I	A	I	A	I	A	I
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												

Grand Total A : ________

Grand Total I : ________

Scorer: ______________________

APPENDIX H
INTEROBSERVER RECORDING FORM

Interval Recording Form

Teacher ____________________ Observer ________________

1. Following Script	20	40	60	20	40	60	20	40	60
2. Following Sequence									
3. Fluent Pacing									
4. Using Materials Correctly									
5. Corrective Feedback									

1. Following Script	20	40	60	20	40	60	20	40	60
2. Following Sequence									
3. Fluent Pacing									
4. Using Materials Correctly									
5. Corrective Feedback									

1. Following Script	20	40	60	20	40	60	20	40	60
2. Following Sequence									
3. Fluent Pacing									
4. Using Materials Correctly									
5. Corrective Feedback									

BIOGRAPHICAL SKETCH

Addison Kent Watanabe was born on September 10, 1951 to Jerry and Ruby Watanabe in Waimea, Kauai, Hawaii. Add is the youngest of three children, and has two sisters. At a very young age, Add and his family moved to the city of Honolulu, Hawaii.

After graduating from high school in 1969, Add pursued an undergraduate degree in biology from Bradley University, Peoria, Illinois. He was graduated from Bradley University in 1973 with a Bachelors of Arts degree.

With a degree in hand, Add entered the U.S. Peace Corps and spent 3 years as a rural public health worker in Lugait, Misamis Oriental, Philippines. As a Peace Corps health worker, he assisted the government physician as an environmental sanitarian, health educator, and laboratory assistant.

At the end of his Peace Corps duties, Add relocated to Ogden, Utah. While living in Ogden, Add attended Weber State University and obtained a secondary teaching certificate for biological sciences. While attending Weber State University, he also started working at the Utah School for the Deaf as a dormitory counselor and supervisor. While working at the Utah School for the Deaf, he started taking classes at the University of Utah to meet certification standards for being a special educator. Upon completion of his coursework, Add secured work at the Utah Schools for the Deaf and

Blind as a teacher for students with hearing impairments. He worked with the school system for 5 years before accepting a position with the Granite School District as a teacher for students with behavior disorders.

In order to work as a teacher for students with behavior disorders, Add again returned to the University of Utah to obtain the necessary coursework for certification. He entered a master's degree program for certifying in learning disabilities and behavior disorders. In December of 1987, Add was confered a masters of science degree in special education from the University of Utah.

In August of 1987, Add entered the doctoral program at the University of Florida. In 1991, he completed a Ph.D. in special education at the University of Florida.

Add would like to conduct research and develop programs to train teachers and paraprofessionals to work with exceptional individuals, design and implement effective instructional procedures, and, to recruit and retain minorities into special education careers. He would also like to continue to research in mathematics education.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Cecil D. Mercer
Cecil D. Mercer, Chair
Professor of Special Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Linda Crocker
Linda Crocker
Professor of
Foundations of Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Cary T. Reichard
Cary Reichard
Professor of Special Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Stuart E. Schwartz

Stuart Schwartz
Professor of Special Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Paul T. Sindelar

Paul Sindelar
Professor of Special Education

This dissertation was submitted to the Graduate Faculty of the College of Education and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 1991

David C Smith

Dean, College of Education

Dean, Graduate School